BBC

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Science Focus

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QUANTUM WEIRDNESS

The future of tech is
SHAPE-SHIFTING

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EARTH'S MYSTERIOUS CORE

SOMETHING STRANGE IS GOING ON AT THE HEART OF OUR PLANET

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Wildlife
The tech uncovering the secret life of whales

E-fuels
How synthetic petrol could save the supercar

Biology
Understand the wonders of the human eye

ADVERTISEMENT FEATURE

AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE CBE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

Your Will can fund the rational response to health challenges that medical science provides.

> **"As scientists, our duty is to secure the future of research for the generations that follow."**
>
> Professor Fiona Watt, Patron of the Medical Research Foundation and Director of the European Molecular Biology Organization.

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.

"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

But many of these scientists rely on the generosity and foresight of fellow members of the medical community who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

Please consider this very special gift today.

Professor Nick Lemoine CBE MD PhD FMedSci
Chair of the Medical Research Foundation

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0623BSF

FROM THE EDITOR

Earth's core is a strange place. Sadly, there are no prehistoric beasts, underground rivers or ancient hominids waiting to be discovered, as Jules Verne imagined in *Journey to the Centre of the Earth*. But there are still plenty of mysteries hidden in its depths. And since we can measure the influence of Earth's core up here on the surface, no one need build a drill-bit-shaped vessel to head down there either. Bummer.

In truth, the behaviour of the planet's heart affects us all. For a start, the days have been getting longer for us surface-dwellers. It probably doesn't feel that way for most of us, but since 2020 the average length of a day – the time it takes for Earth to rotate on its axis – seems to have been growing. Scientists think something unexpected, deep within the centre of the planet, might be slowing its spin, causing the days to extend – albeit by microseconds.

In a similar vein, Earth's magnetic field, which is generated by our molten iron core and protects us from the Sun's most lethal radiation, is changing too. Over the last 200 years the global average strength of the field has fallen by nine per cent. A spot over South America, known as the South Atlantic Anomaly, where our planet's magnetic shield is weakest, is moving and waning at an even faster rate, causing satellites in the vicinity to fail as a result of the extra radiation bursting through from space.

These are just a couple of the surprising discoveries that have been made over the last few years thanks to an influx of new technologies and techniques for studying what's going on deep in the heart of the planet we call home. Enjoy the whole cover story over on p66.

Daniel Bennett, Editor

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COVER: MAGIC TORCH THIS PAGE: GETTY IMAGES X2, ALAMY, DANIEL BRIGHT

ON THE BBC THIS MONTH...

Crowd Science:
What's living inside my gut?
Your innards play host to a multitude of microbes, some that can affect your health and others that can even influence your mood. In this episode the team shares the latest info on what we know about the human microbiome.
BBC World Service,
Also available on BBC Sounds

Inside Science:
Science in the making
Victoria Gill and the Inside Science team sneak (with permission) behind the scenes at the Royal Society to witness the incredible collection of scientific treasures stored in its archives, including Newton's death mask!
BBC Radio 4,
Also available on BBC Sounds

Discovery: Psychedelics
A new wave of research is revealing the promise of hallucinogenic drugs for treating severe mental health conditions. But with the hype, comes risk and there is still much to learn.
BBC World Service,
5 June 8:30pm (BST)

What is the power pose? And will it really boost my confidence before a job interview? →p75

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LIBBY JACKSON
Libby is the head of space exploration at the UK Space Agency. We asked her to delve into the idea that future long-duration space missions should feature all-female crews. →p38

COLIN STUART
The award-winning astronomy author, writer and speaker tackles the seismic changes that are occurring in our understanding of the Earth's core. →p66

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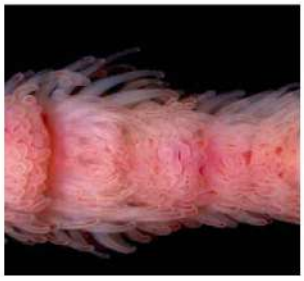

Whether a chicken grows feathers or scales is decided by one gene, named after Sonic the Hedgehog.

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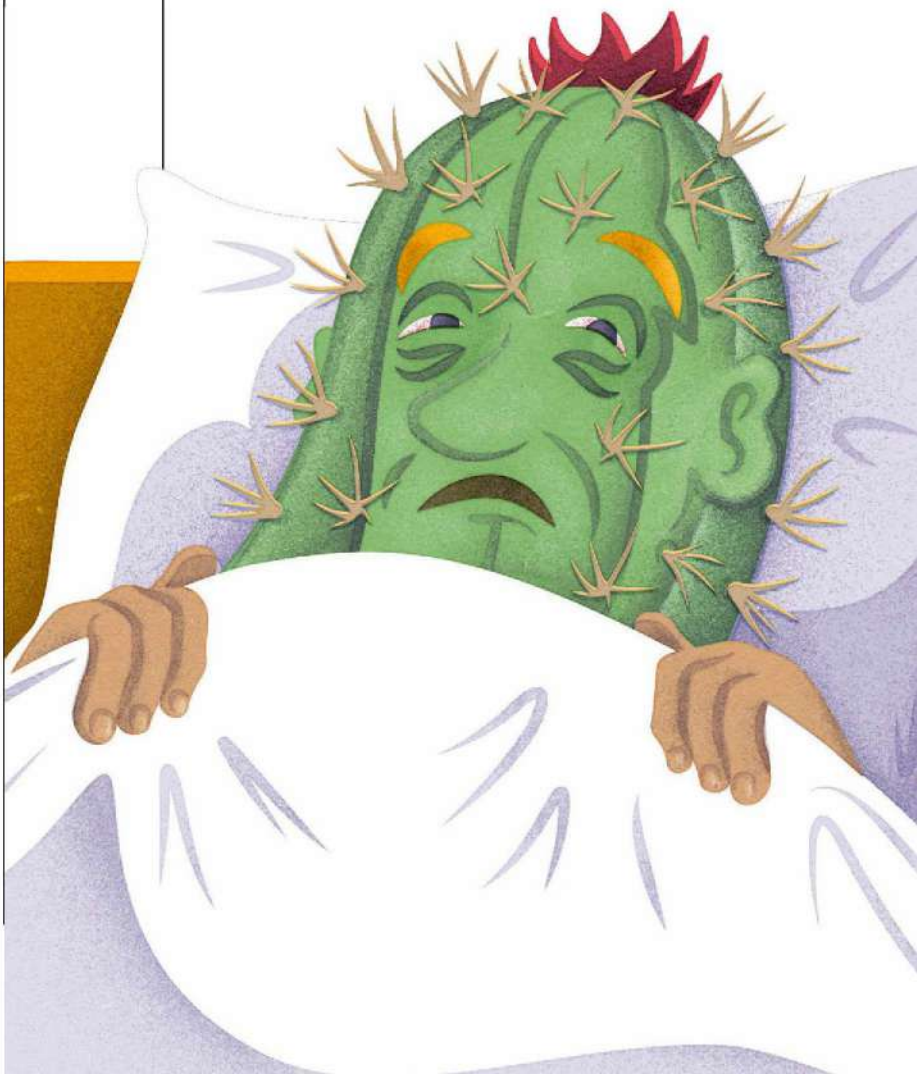

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Whether it's wood, wool or ink, you can do some incredible things with these materials if you know how to exploit their natural characteristics.

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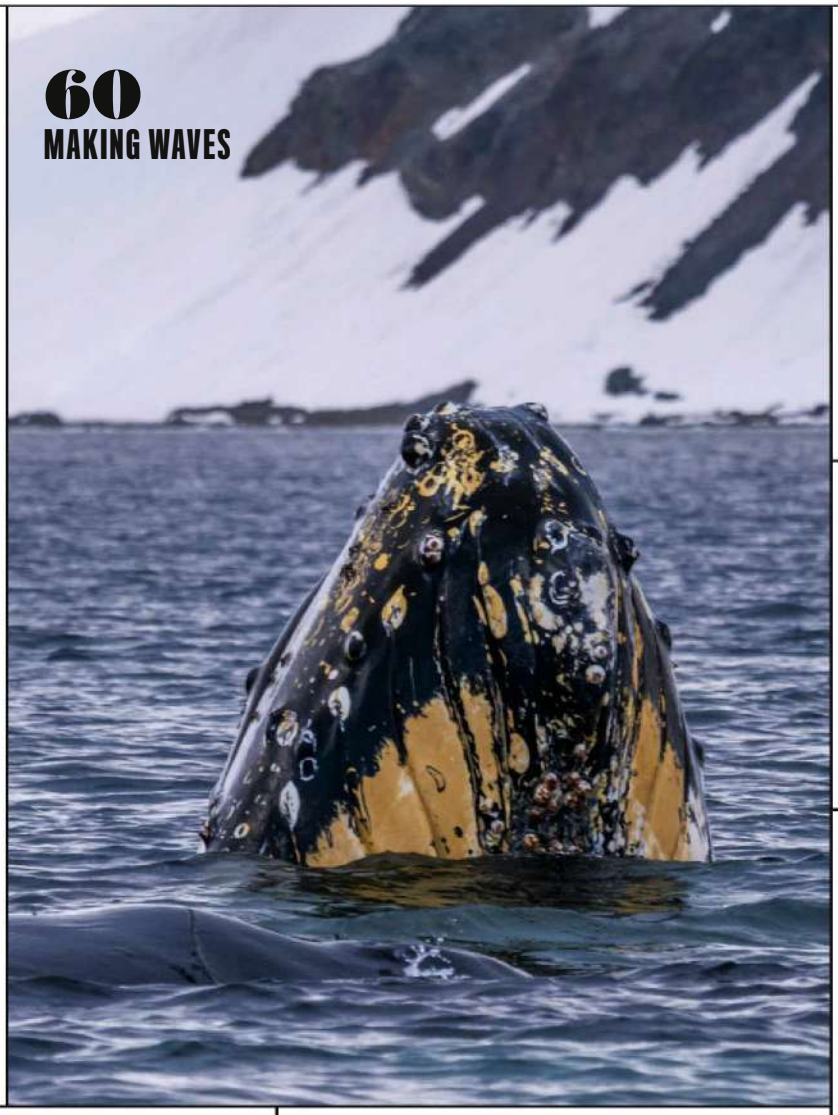

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EYE OPENER

A sharper image

NORTH CAROLINA, USA

Science has come a long way since the first magnetic resonance imaging (MRI) scan was performed on a human, almost 50 years ago. This new scan, of a mouse's brain, looks more like an elaborate firework than the inner workings of this complex organ but it's the sharpest scan of a brain that has ever been taken.

To capture this image, a supercomputer with the processing power of 800 laptops was developed by a cross-university team led by the Duke Center for In Vivo Microscopy. While there's still a long way to go, it shows the incredible future that MRIs can offer.

This image is roughly 64 million times sharper than a scan that could be captured by current clinical MRI technology. With a scan this detailed, it's possible to spot a brain tumour and capture intricate details of its structure. With this level of detail, researchers hope to better understand how the brain changes with age, as well as a number of diseases such as Alzheimer's.

DAN VAHABA/DUKE INSTITUTE

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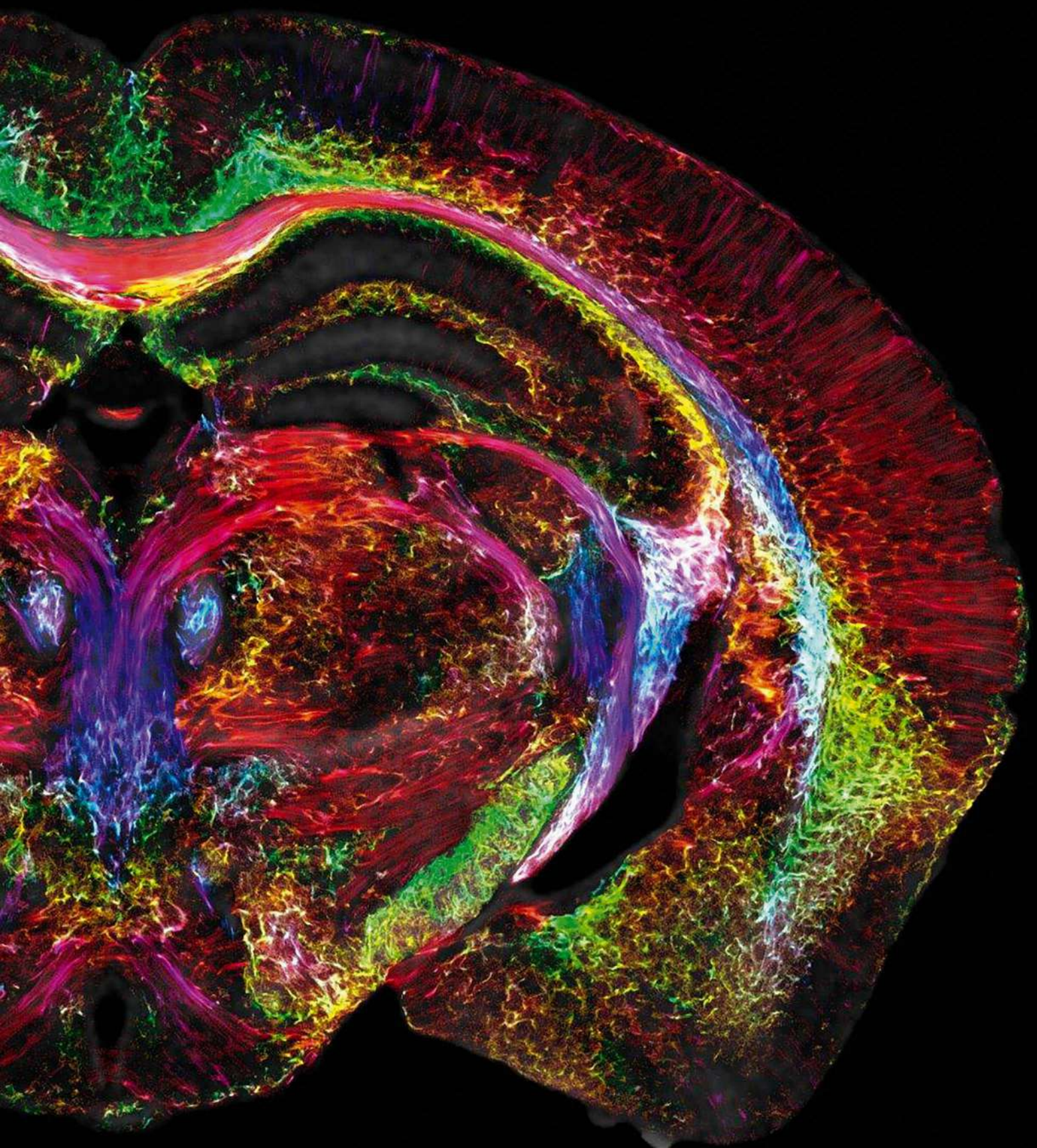

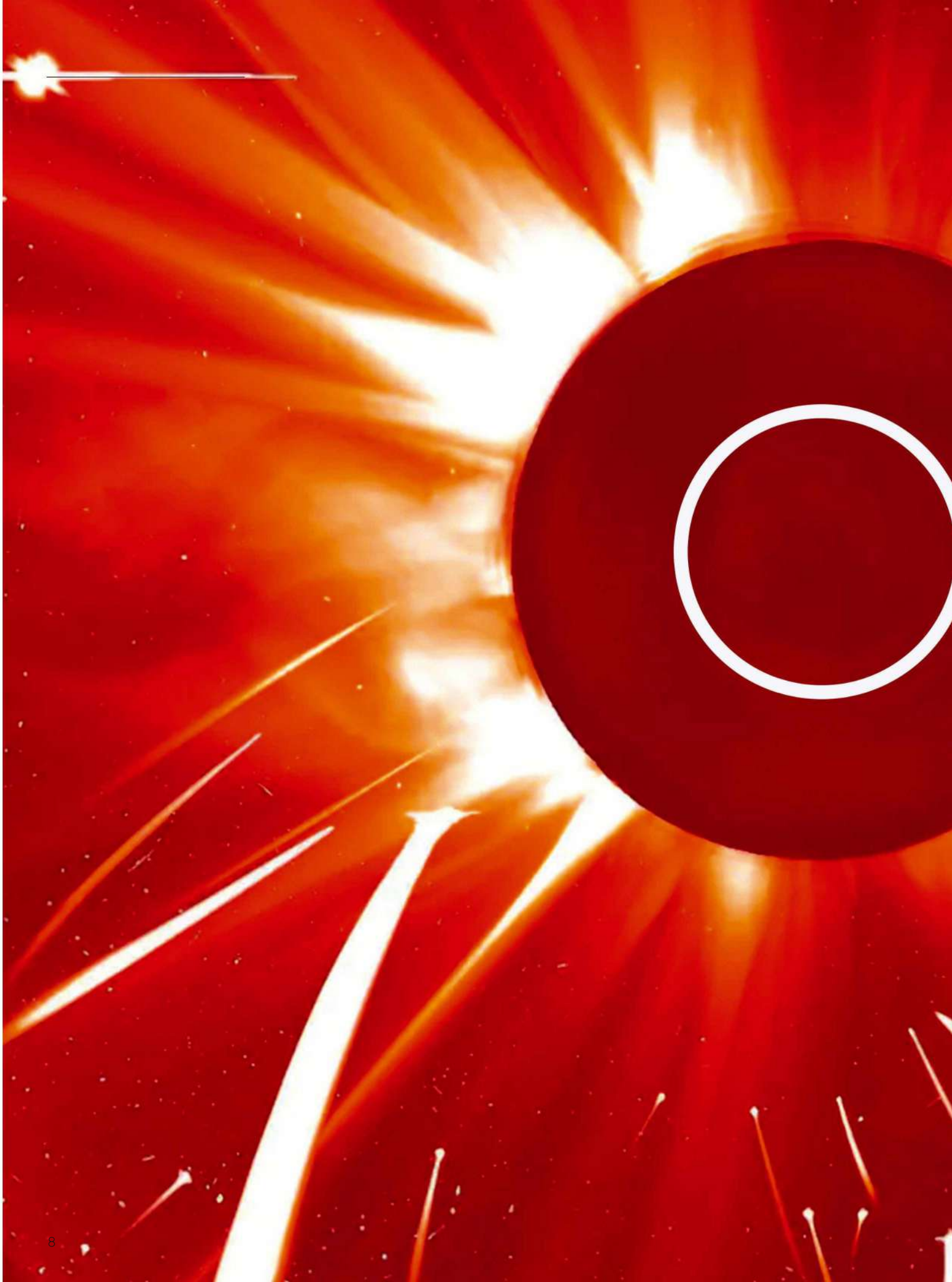

EYE OPENER

Sunseekers

Who says you need a huge, cutting-edge telescope on top of a mountain to discover a comet? Especially not when you can search for these celestial visitors from the comfort of your sofa. That's exactly what citizen scientists from around the world have done in the Sungrazer Project (sungrazer.nrl.navy.mil) and this stunning composite image is the result. It shows some of the brightest comets ever observed by the Large Angle and Spectrometric Coronagraph (LASCO) on the Solar and Heliospheric Observatory (SOHO), a joint ESA and NASA spacecraft.

Stationed around 1.5 million kilometres away from Earth, SOHO watches the Sun and studies its corona – the star's outer atmosphere. Each of the streaks of light in this image is an icy comet that brightens as it gets closer to the Sun. The dark area in the centre is SOHO's occulting disc, which blocks out the Sun's glare, allowing us to see the fainter features around it.

Over 4,500 comets have been found by the Sungrazer Project, that's over half of all known comets. "SOHO is the most prominent comet-hunter, with a huge catalogue of discoveries still awaiting analysis," says Dr Karl Battams, of the SOHO and Sungrazer Projects.

NASA/ESA/SOHO

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EYE OPENER

Going with the flow

SYDNEY, AUSTRALIA

The common purple janthina's fate rests entirely in the hands of the ocean. The marine mollusc spends most of its life bobbing along just below the sea's surface, clinging to the bottom of a raft made of mucus bubbles blown from a gland in its foot. The janthina can't swim, so if its bubble raft bursts, the 4cm-long snail will sink to the seabed and die. To avoid such potentially fatal punctures, the snotty bubbles it blows harden into a rubber-like material.

But being unable to swim means the janthina is unable to steer its raft, so it travels entirely at the whim of the ocean's currents. If it's lucky, the janthina will bump into a hydrozoan, such as the Portuguese man o' war – its favourite prey. But there's no guarantee and, as a recent study reported, the snail's got just as much chance of ending up in the Great Pacific Garbage Patch. This outcome is not altogether bad though, as it's become something of a feeding ground and nursery for janthinas. It's also good for the scientists studying them. "They're usually hard to find" said Fiona Chong, one of the study's authors. "The Garbage Patch is giving us an chance to learn more about janthina."

REG MORRISON/AUSCAPE/MINDEN

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

Ball lightning is yet to be explained. Is it gas? Plasma? Or something else?

Is ball lightning really a physical phenomenon?

Several decades ago, I saw what I think was ball lightning. I was in the kitchen of my parents' guesthouse in Wharfedale, Yorkshire. There were three other people in the room with me and more folk in the same building and we all saw a glowing ball, about the size of a football. For me, it quickly vanished as it passed out of the open window but it left with a bang and we were all deafened for several minutes afterwards.

As a physicist, I was intrigued by the event and researched the observations. There were about a dozen people in the house at the time, most of whom were in the lounge. They all reported that the ball they saw was between themselves and where they were facing – in front of the fire for those people in the lounge – and I concluded it was seen wherever they happened to be looking. Meanwhile, a lady upstairs saw the ball vanish as it went around a corner in the bathroom! No one reported more than one ball but we all saw it in different rooms at the same time!

As for the telephone wires in the house, blobs of copper had melted in their plastic covers, while the phone's battery cells had exploded. These observations implied a high current for a very short time and all the phone wires had to be replaced.

Since this event, I have looked at many reports of ball lightning, including some reported in aircraft where they're generally 'seen' in the direction that the person was (probably) facing: towards the front of the cabin. I have concluded that these phenomena are all the effect of a large electromagnetic field pulse on the human brain and likely cannot be photographed.

Prof Joshua Swithenbank, via email

WRITE IN AND WIN!

The writer of next issue's *Letter of the Month* wins ***a bundle of the latest hardback science books***. Put pen to paper (or fingertips to keyboard) and you could get your hands on *Unwired* by Gaia Bernstein; *The Limits Of Genius* by Katie Spalding; and *My Father's Brain* by Sandeep Jauhar.

WORTH OVER £60

Not while I'm eating lunch!

I really enjoyed reading, and was fascinated by, 'The Wonderful World of Slime' (March, p60), although it did put me off my lunch, which I was eating at the time! I had no idea that slime was so widespread and plays such an important part in life. It was interesting to learn that it most likely played a key role for early life and in the microbial communities that first dominated life. I do also agree with zoologist Dr Arik Kershenbaum's assertion that we will find life on other planets soon and that it will be slime!

Luke Russell, Tingley

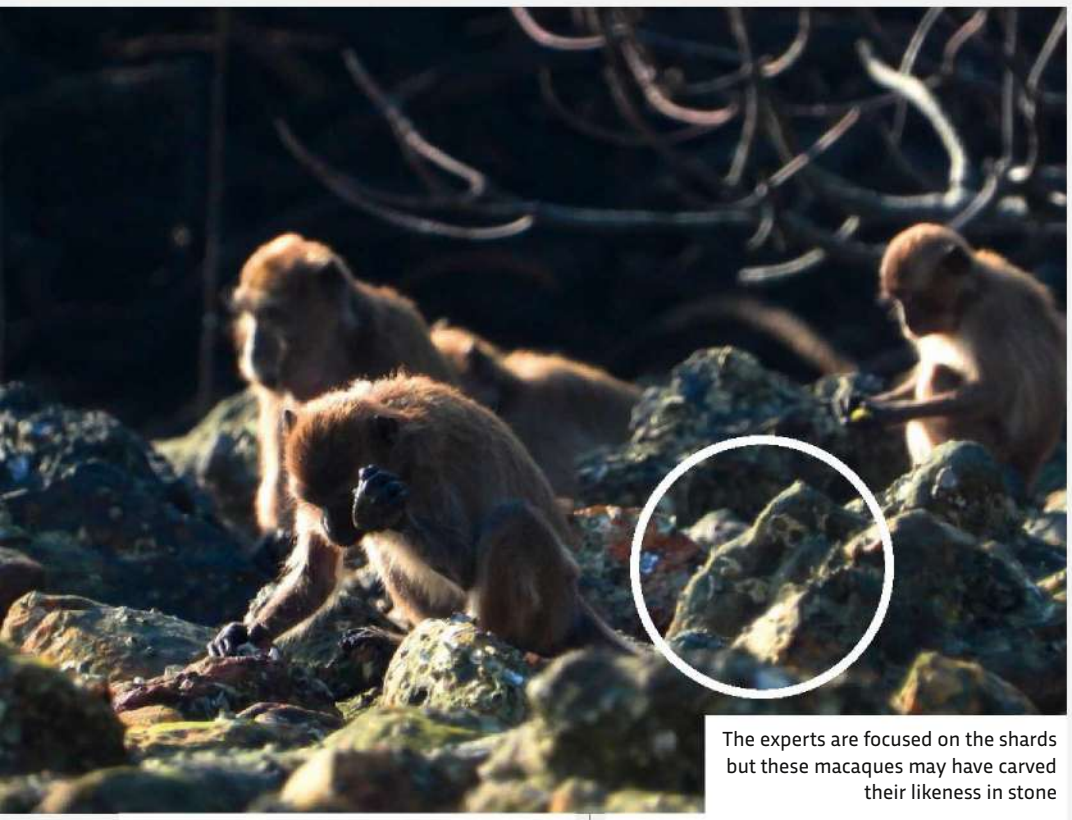
It may look disgusting, but slime is a vital part of life

Are we all aliens?

A recent 'Discoveries' story (April, p21) posits that samples of organic compounds collected from an asteroid by the Japanese spacecraft Hayabusa support the 'Panspermia' hypothesis. While I agree there is certainly evidence that points in this direction, I have always felt the notion of life on Earth originating from elsewhere in the Universe raises far more questions than it answers. If the seeds of life were indeed flown in, where did they originate? Asteroids are thought of as barren rocks, devoid of atmospheres and are remnants of earlier times in the Solar

"TO BE CLEAR, 100 PER CENT OF THE BRAIN IS USED... FOR SOMETHING. WE MAY NOT KNOW WHAT BUT IT'S DEFINITELY THERE FOR A REASON"

DR DEAN BURNETT, P34



The experts are focused on the shards but these macaques may have carved their likeness in stone

SCIENCE PHOTO LIBRARY, LYDIA V LUNCZ, GETTY IMAGES

System. What processes led to the formation of these organic compounds, and how are they distributed throughout space? If a large enough proportion of asteroids carry the components for life as we know it, and asteroids collide with planets as often as we think, how many worlds might be populated? How many seeds are out there still waiting to be planted?

Jamie Williams, via email

Monkey business

The interesting 'Discoveries' story about long-tailed macaques and the shards of stone they have created in Thailand (April, p23) does not give these monkeys the full credit they deserve. The monkeys appear to be much further along the evolutionary path than the researchers actually realise. If you look closely at the picture that accompanied the story (above), you may see that the artistic macaque in the foreground seems to have carved a statue of its kind and placed it behind itself before processing its lunch! Great magazine!

Tom, via email

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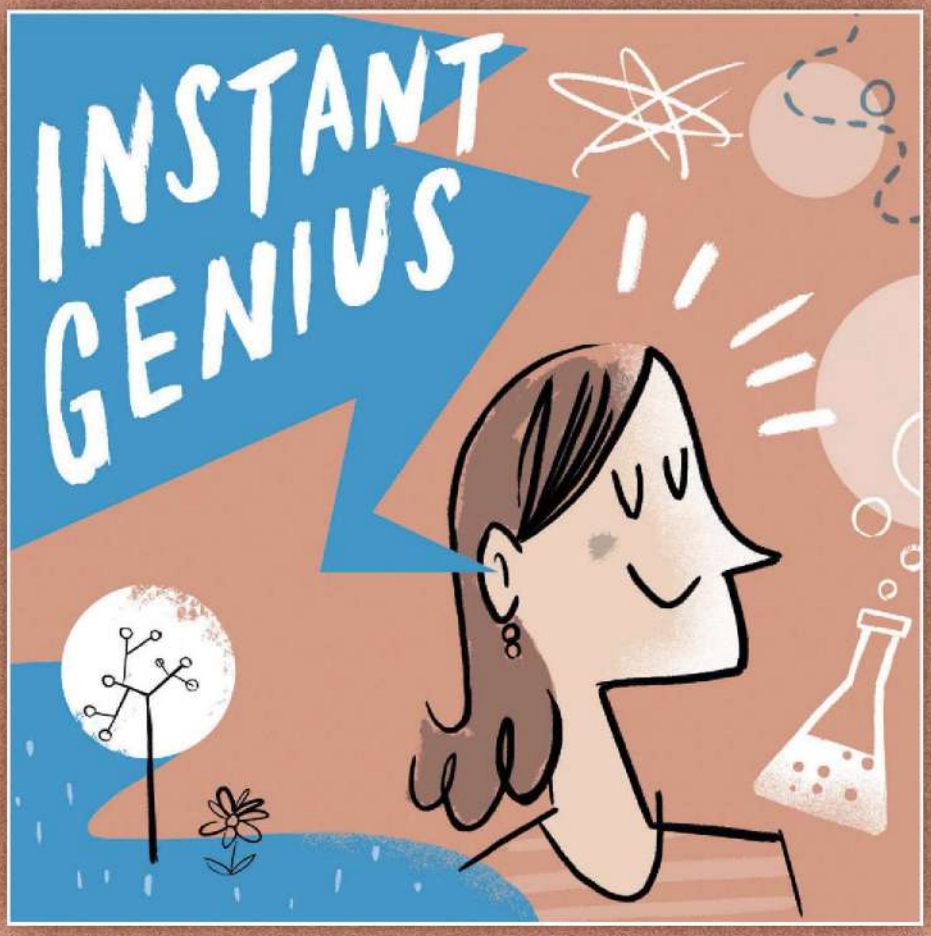

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"Advanced civilisations may be capable of observing the radio leakage from Earth"

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Aliens could be listening into our radio broadcasts **p23**

ESO/M KORNMESSER

An artist's impression of the surface of a planet near Barnard's Star, where it would be possible for advanced civilisations to receive our radio broadcasts

GENETICS

A GENE NAMED AFTER SONIC THE HEDGEHOG IS ALL THAT SEPARATES SCALES FROM FEATHERS

A recent discovery shows that changes in an unusually named gene can turn a scaly animal into a feathered one

ABOVE Chicken's feet showing how those with the *Shh* gene switched on developed feathers

ABOVE RIGHT Feather bud development was evident on the chicken embryos as early as 11 days into their development

Despite their clear differences, new research shows that just a few genes separate the growth of scales from feathers in animals, and it all has to do with a gene named after Sonic the Hedgehog.

Appendages from the skin such as hair, feathers and scales are common and diverse across mammals, and they're all created when skin cells harden in the necessary areas of the body. It's a certain cluster of genes that influence this hardening – one of the most important being the Sonic Hedgehog gene (or the *Shh* gene).

In a recent experiment, a team led by Michel Milinkovitch – a professor in the Department of Genetics and Evolution at the University of Geneva – investigated the potential role of the *Shh* pathway.

The *Shh* gene controls the signalling pathway: a communication system that allows the transmission of messages between cells. The signalling pathway

UNIGE/COOPER & MILINKOVITCH X2, ALAMY

Why 'Sonic the Hedgehog'?

We're not telling you to be quiet: *Shh* is short for Sonic Hedgehog gene. The name came from Dr Robert Riddle, who wanted to break the mould when the other developmental biologists in his lab at Harvard Medical School decided to name each newly detected gene after a (real) species of hedgehog. The three previous to *Shh* were named Indian hedgehog, moonrat hedgehog and desert hedgehog.

"Hair, scales and feathers are similar structures inherited from a reptilian ancestor"

also helps to build skin appendages and the neural tube (the early stages of the brain and spine).

The researchers found that, by activating the *Shh* pathway in chicken embyros, they were able to trigger the formation of feathers on the chickens' feet, where there would normally be scales.

"We used the classic technique of 'egg candling', in which a powerful torch illuminates blood vessels on the inside of the eggshell," said Rory Cooper, a post-doctoral researcher in Milinkovitch's laboratory and co-author of the study.

"This allowed us to precisely treat chicken embryos with a molecule that specifically activates the *Shh* pathway, injected directly into the bloodstream".

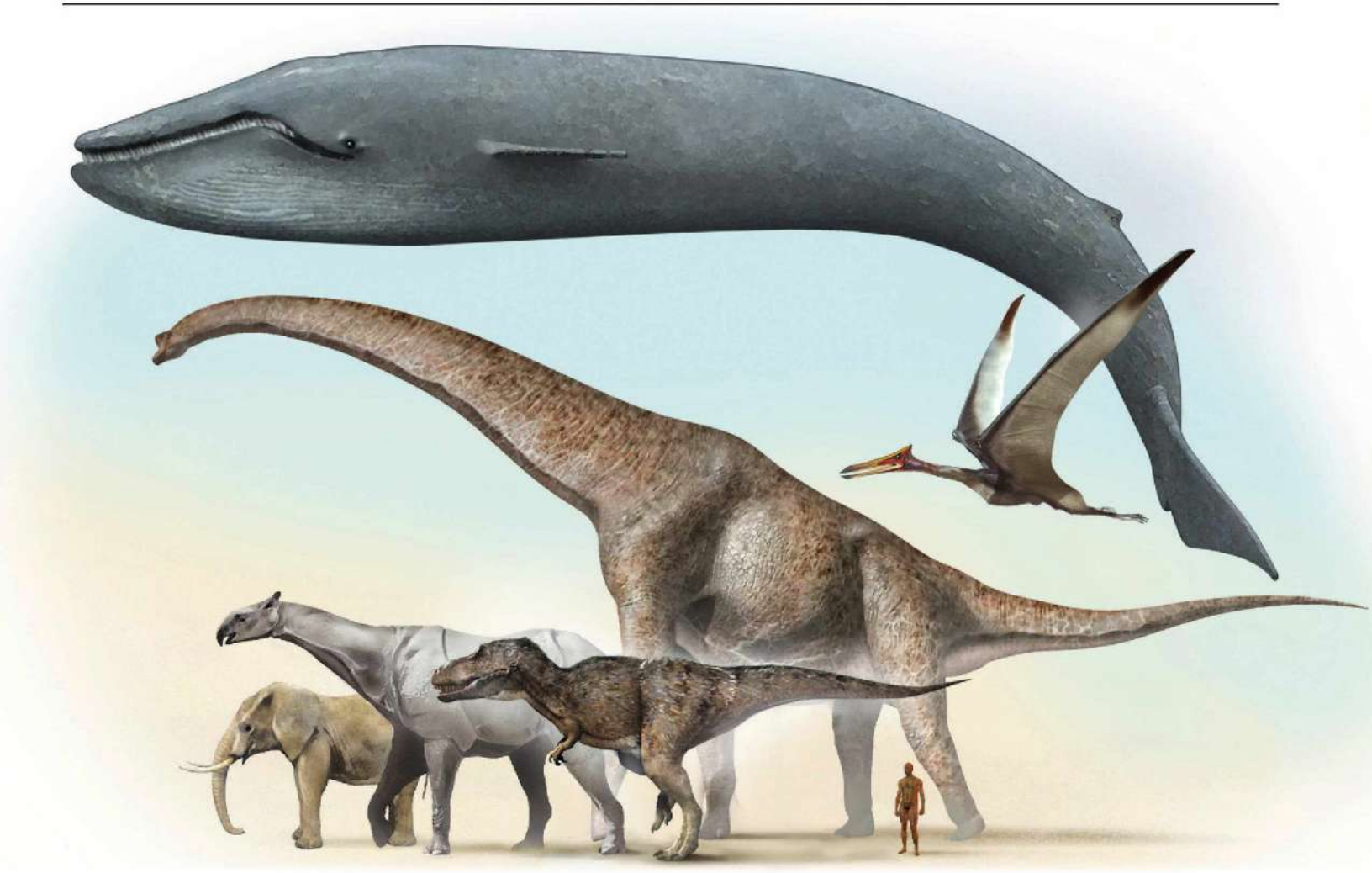
The study, published in the journal *Science Advances*, follows previous work from Milinkovitch's lab demonstrating that hair, scales and feathers are similar structures inherited from a reptilian ancestor.

''Our results indicate that an evolutionary leap – from scales to feathers – does not require large changes in genome composition or expression. Instead, a transient change in expression of one gene, *Shh*, can produce a cascade of developmental events leading to the formation of feathers instead of scales,'' said Milinkovitch.

PALAEONTOLOGY

BREAKTHROUGH STUDY REVEALS HOW SUPER-MASSIVE DINOSAURS GOT SO BIG

The sauropods were the largest animals to ever walk on Earth. A new study explains how they got that way



SCIENCE PHOTO LIBRARY, SHUTTERSTOCK, TODD OSBOURNE

ABOVE
Brachiosaurus (centre) was the largest sauropod, and the largest-ever land animal

ABOVE RIGHT
A giant sauropod footprint is visible on a rock, with a human foot for comparison

Back when our ancestors were just rat-sized creatures crawling along the floors of prehistoric forests, super-giant sauropod dinosaurs browsed the treetops. But how, and when, did they get so big?

Palaeontologists at Adelphi University, in the US, have figured out that they reached their exceptional sizes in order to fill the available niches, and that they managed it by evolving many more times than previously thought.

"There is no one key factor, event or evolutionary innovation that led to sauropods becoming the largest animals ever to walk the Earth," Dr Michael D'Emic, an associate biology professor at Adelphi University, told *BBC Science Focus*. "Instead, it seems that it was 'right place, right time, right circumstances'."

Rather than each species changing its size a couple of times throughout its evolution, D'Emic discovered that individual species of large sauropod species actually evolved as many as 36 times over 100 million years.

D'Emic, whose study was published in *Current Biology*, was able to calculate this by estimating the body mass of around 200 sauropod species based on their limb dimensions, before mapping these masses

“The biggest sauropods evolved to be over 30m and weigh as much as 60 tonnes (about 15 average African elephants)”

onto the group’s evolutionary tree. The study reveals that with each new sauropod family that emerged, at least one lineage independently became super-giant.

The first sauropods were about six metres long and weighed around 800kg (about the same weight as an average rhino). The biggest evolved to be over 30m, like the iconic long-necked brachiosaurus, and weigh as much as 60 tonnes (about 15 average African elephants). To make a comparison, that’s equivalent to humans evolving to become five times taller, or 75 times heavier.

“People tend to think of mammals as more advanced than dinosaurs in an evolutionary sense – after all, dinosaurs are a symbol of extinction,” said D’Emic. “So it’s ironic that it is the more ‘reptilian’ characteristics of sauropods [such as laying large numbers of eggs to increase the chances of their offsprings’ survival], that likely allowed them to become the largest animals ever to walk on land.”

GENETICS

YOUR DNA IS TURNING UP IN PLACES YOU LEAST EXPECT IT

A new study reveals human DNA can be retrieved from almost anywhere and be used to identify you

We leave genetic traces of ourselves everywhere we go, through dropping dead skin and hair, sneezing and coughing, or flushing the toilet after we’ve used it. Now, scientists from the University of Florida found have discovered that not only can these DNA traces be retrieved from land, sea and air, but also that they’re strong enough to be matched to individuals. The scientists found human DNA almost everywhere – in oceans and rivers, and buried in the sand of beaches.

ABOVE DNA traces that could be used to identify an individual could be collected from the sea

“We can’t just ignore that there’s all of this human data potentially being accumulated,” said Dr David Duffy, an assistant professor of wildlife disease genomics and co-author of the study that reported these findings. Given the privacy implications of this, he thinks policymakers and scientists need to figure out and implement precautions and safeguards for collecting and handling material of this nature.

According to Duffy, the DNA samples they found allow the same level of advanced study as DNA taken directly from individuals. “What was surprising was the quantity and quality,” he said.

The study published in *Nature Ecology & Evolution* reveals that this is such high-quality DNA that the scientists would have been able to sequence it to identify the owner’s genetic ancestry, or detect mutations linked to genetic diseases like autism and diabetes.

They only sequenced the DNA of volunteers who had consented. While investigations will often share a study’s findings, in this case that would mean sharing sensitive information about specific individuals. The authors warn that, in the future, this could enable the tracking of individuals or ethnic groups through the environment.

The study highlights a need for policymakers to tackle issues of consent and privacy when it comes to recording the biological material fragments found in ecosystems called environmental DNA (e-DNA). “This collection of human e-DNA is an issue that’s going to grow over time,” said Duffy.

Scientists used a not-so-subtle device to monitor the neural signals in goldfishes' brains. Can you spot it?

NEUROSCIENCE

CYBORG FISH SHOWS SCIENTISTS HOW BRAINS HANDLE NAVIGATION

Researchers finally explain how fish learn and remember their environment... despite their reputation for having a bad memory

No, this isn't the aquatic version of Royal Ascot. The hat-wearing goldfish pictured here is actually one of the stars in a new study explaining how the fish navigate in water – something we haven't been able to understand, until now.

This "cyborg fish", as Prof Ronen Segev, a neuroscientist at Israel's Ben-Gurion University, calls it, was one of several used in the study. "Studying fish presents a real opportunity for brain science," Segev told *BBC Science Focus* and it's all thanks to that hat.

For the study, published in *PLOS Biology*, the team Segev was part of used recording devices to measure a neuron in a part of the fish's brain that is associated with navigation. Recording the fish as it swam along channels in a tank helped the team identify boundary vector cells, which respond to an animal's direction and distance from a boundary, and are similar to those found in rats – suggesting that mammals share some navigational tools with fish.

But, unlike land-based mammals, the goldfish's boundary vector cells allow it to move in 3D environments. Humans don't live in a flat, 2D world but, unlike terrestrial creatures, fish must navigate horizontally, diagonally and vertically.

So what's actually in the hat? What looks like a stack of luggage is actually electronics that capture the neural signal, amplify it and then store it on a memory chip. The team then uses that data to plot the fish's neuron activity against its motion, as detected by a camera in front of the tank.

The next step for the team will be sending cyborg fish into the semi-natural environment of a pond. Here, the team will track the neuron activity of the fish while they interact with other fish in a larger environment.

According to Segev, the other fish aren't too bothered by the 'hat-wearing' cyborgs. "They don't seem to care. We initially thought the device might weaken the fish and that it might be attacked by others but it didn't happen."

He adds: "Fish are extremely important for the environment – so it's vital that we understand their physiology and the how they behave. [Studying their] navigation helps us learn about the fishes' understanding, learning and memory, which is why it's such an important aspect of behaviour and brain science."

LEAR COHEN, LUIS FELIPE GUANDALIN ZAGATTO

CONSERVATION

DARK EARTH: SCIENTISTS UNVEIL A NEW 'SECRET WEAPON' TO COMBAT DEFORESTATION

Ancient soil from the heart of the Amazon could help restore the planet's depleted rainforests

Scientists may be able to protect the future of the world's forests by using remnants from the past, in the form of a thick, black soil buried deep in the Amazon rainforest. It's called 'Dark Earth'.

Transformed from poor-quality soil by centuries of deposits from indigenous peoples, Dark Earth could now be the 'secret weapon' we need to restore forests across the globe, according to a new study from the University of São Paulo, Brazil. The scientists found that tree species grow as much as six times taller in Dark Earth than in normal soil.

Amazonian Dark Earth (or ADE) comprises ancient sediments of day-to-day life, including charcoal from fires for cooking and burning waste, animal bones, broken pottery, compost and manure. These were created by millions of Amerindian people between 450 BC and AD 950.

The charcoal is particularly good for making the soil fertile and nutrient-rich, as well as providing its distinctive black colour. Crucially, the soil also contains an abundant microbial community of helpful bacteria and archaea (another type of single-celled micro-organism).

"Microbes transform chemical soil particles into nutrients that can be taken up by plants," explains the study's joint lead author Anderson Santos de Freitas. Dark Earth's combination of micro-organisms is especially good at unlocking more resources than usual to help plants grow.

Knowing the combination of ingredients that make Dark Earth so fertile will help the researchers share the recipe with reforestation projects across the globe. But the researchers won't be sending out the soil itself: "Amazonian Dark Earth has taken thousands of years to accumulate and would take an equal time to regenerate in nature if used," said senior author Prof Siu Mui Tsai.

"Our recommendations aren't to utilise the Amazonian Dark Earth itself but rather to copy its characteristics, particularly its micro-organisms, for future ecological restoration projects."

The study, published in *Frontiers In Soil Science*, involved conducting micro-reforestation experiments. The scientists used Dark Earth from the Brazilian state of Amazonas, normal agricultural soil from São Paulo, and a mixture containing 20 per cent Amazonian Dark Earth.

They discovered that the plants they grew were up to 6.3 times taller in Dark Earth than in normal soil. One of the species, Ambay pumpwood (an important species in young forests) did not grow at all in the normal or even the combination soil but thrived in the Dark Earth.

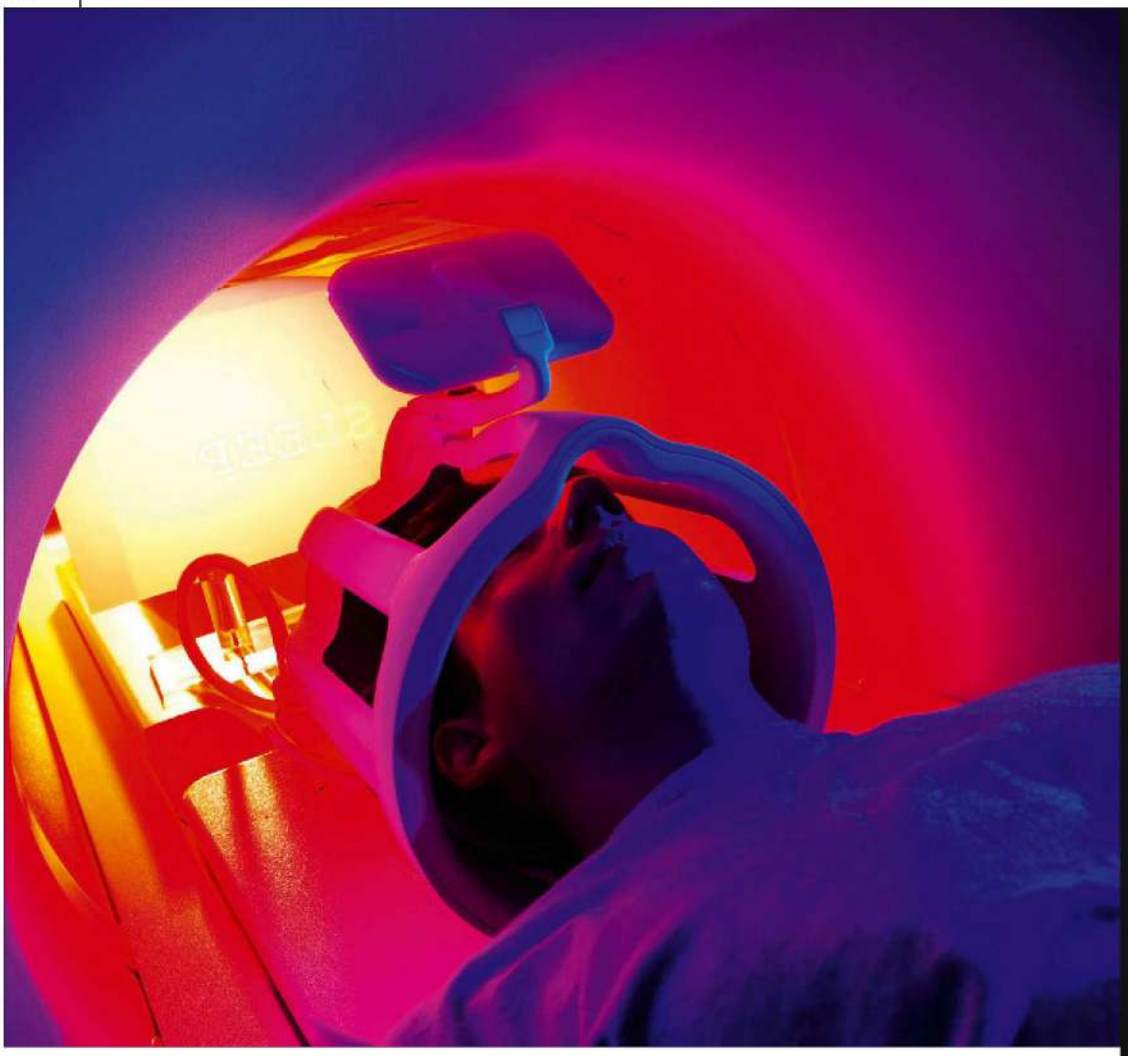
Amazon rainforest in numbers

6.7m
The rainforest covers an area of 6.7 million km²

18%
The amount of the Amazon lost since the 1970s

2 million
The Amazon is home to over 2 million indigenous people

150+ bn
The amount of carbon, in tonnes, stored in the Amazon's forests and soils



NEUROSCIENCE

THIS MACHINE CAN READ YOUR MIND AND TRANSLATE HOW YOU SEE THE WORLD

Neurotechnologists have developed a decoder that can reconstruct what you're seeing, thinking and imagining... and put it into words

A machine that reads your thoughts is now more science fact than science fiction, following a breakthrough discovery by neurotechnologists at the University of Texas at Austin (UT Austin).

The machine doesn't require its subject to be wired up with implants and electrodes. Instead, the 'decoder' is non-invasive, using functional magnetic resonance imaging (fMRI) to measure the changes in blood flow around the subject's brain to translate their ideas into words.

"We're decoding something that's deeper than language," said Alexander Huth, an assistant professor of neuroscience at UT Austin. The decoder can grasp the intangible – the various shapes our thoughts take – and turn them into something understandable and, crucially, communicable.

This means that the person who is having their mind 'read' doesn't have to say what they're thinking. For those who have lost the ability to speak – following a stroke, for example – the decoder could restore communication channels non-invasively.

"Speech impairments can be highly debilitating," said co-author Jerry Tang, a graduate student at UT Austin. "Providing some sort of additional communication channel could be really valuable."

The machine is discussed in a paper, published in *Nature Neuroscience*, and is said to work by combining well-established decoding methods with modern machine learning techniques. Essentially, it works in a similar way to the AI tool ChatGPT, by predicting the ends of sentences based on what has been learnt before.

What does this mean for brain privacy?

For many, the prospect of a machine that reads thoughts sets alarm bells ringing. But the researchers stressed that the current model can only be used on the individuals it has been trained on. It also needs a participant's cooperation to work, as the study found that participants could resist being 'decoded'. They called this process "sabotaging the decoder" and it involved participants performing simple tasks (counting, naming animals or telling their own story) to 'distract' the decoder from other thoughts.

Future technology may be able to get around this and, to that end, the researchers highlighted the importance of researching privacy implications. "While this technology is in its infancy, it's important to regulate what brain data can and cannot be used for," says Jerry Tang. "It's important to make sure that the decoder's capabilities aren't misrepresented."

ALAMY X2

ALIEN LIFE

ALIENS COULD SOON DETECT LIFE ON EARTH, ALL THANKS TO OUR MOBILE PHONE MASTS

Only aliens with more advanced technology than us would be able to 'eavesdrop' on the signals transmitted on Earth. But apparently that's more likely than you might think

While we search for signs of life beyond Earth, radio signals 'leaked' from our mobile phone towers could be helping extra-terrestrials find us.

According to a new study, these radio signals are not currently strong enough on their own to be detectable by alien civilisations – assuming they're using the same technology as we are to find them. But if these civilisations have more advanced technology, and are looking at radiation from additional sources (such as Wi-Fi networks), we could soon be discovered by extra terrestrials in nearby star systems.

"I believe that there's every chance advanced civilisations are out there, and some may be capable of observing the human-made radio leakage coming from Earth," says Dr Nalini Heeralall-Issur, a physicist from the University of Mauritius and co-author of the study.

Published in the *Monthly Notices of the Royal Astronomical Society*, the study used data from mobile phone towers to simulate the signal leakage that could be detected from nearby stars, if the civilisations there had detection technology equivalent to the USA's Green Bank Telescope. Among them were Barnard's Star (in a system six light-years from Earth that contains potentially habitable planets), HD 95735 and Alpha Centauri A.

The researchers behind the study claim that most alien civilisations are likely to have more sensitive signal detection technology than ours. Also, as our broadband systems become more powerful, our detectability is likely to increase further.

While television transmission leakage has weakened since the advent of cable and internet TV, Earth's 'radio leakage signature' now consists of strong mobile radio signals as well as radar, digital broadcast systems, Wi-Fi networks and recently launched satellite constellations.

Despite claims that Earth has been getting increasingly 'radio quiet', the study's project leader Prof Mike Garrett from the University of Manchester said that "the integrated spectrum of billions of these devices is substantial."

Simulating the detectability of TV and digital broadcast system signals will be the next step for the researchers. According to Garrett, "Earth is already anomalously bright in the radio part of the spectrum. If the trend continues, we could become readily detectable by any advanced civilisation with the right technology.

The Green Bank Telescope, USA. If aliens around six light-years away had a device like this, they may well be able to detect the signals leaking from our mobile phone towers

THE FUTURE'S BRIGHT...

As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From virtual reality devices that could help amnesia sufferers to fuels made via photosynthesis, here you'll find many reasons to feel hopeful about our future...

A NEW ERA FOR ALZHEIMER'S TREATMENTS

Two new drugs that slow the progression of Alzheimer's have been developed. The latest – a drug called donanemab created by the company Eli Lilly – has been reported to slow the pace of Alzheimer's by about a third. It works by clearing amyloid beta– a sticky substance that forms a plaque in the brains of people with Alzheimer's disease. Those given the drug were able to live 'normal' lives for longer, continuing activities like driving, pursuing hobbies, or discussing current events. Before the drug can see widescale use, however, Eli Lilly needs to reduce the drug's side effect of brain swelling.

YEARS TO GO

25

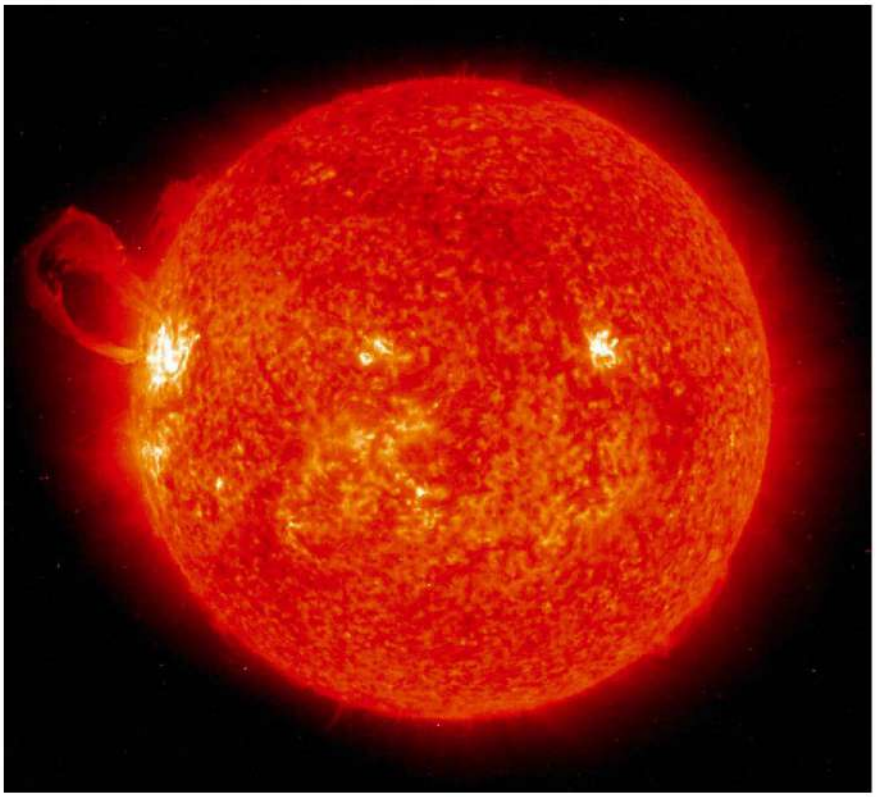
POTENTIAL ANTIDOTE FOR DEATH CAP MUSHROOM POISONING

Foragers, rejoice. A substance found to reduce the toxicity of the death cap mushroom has been approved by the US Food and Drug Administration for use in human cell lines and mice. Death caps are the world's most poisonous mushroom, responsible for over 90 per cent of deaths by mushroom poisoning around the world. Alpha-amanitin, the toxin produced by the death cap, causes irreparable liver and kidney damage but until now, there have been no antidotes. A research team at Sun Yat-sen University, China used genome-wide CRISPR screening (a gene-editing technique) to test a substance called indocyanine green as an antidote and found that it increased the probability of survival in human cell lines and mice. The next steps will be assessing the indocyanine green's safety for use in humans.

20

DRIVING ON SUNSHINE WITH PHOTOSYNTHESIS FUEL

Researchers from the University of Cambridge have worked out how to harness sunshine to create fuel using artificial leaves. Just like the natural process of photosynthesis, the solar-powered technology converts carbon dioxide and water into a liquid – bioethanol – than can be added directly to a car's engine. The technology is still at laboratory scale and needs to be made more efficient but it could be an important step in moving away from fossil fuels. A cleaner alternative to petrol, solar fuels also produce net zero carbon emissions and don't require large tracts of land to grow crops, unlike most biofuels.



AN EARLY-WARNING SYSTEM FOR SOLAR STORMS
Scientists at the University of Reading have found that satellite data that's returned to Earth rapidly could improve the accuracy of solar wind forecasts by almost 50 per cent. Solar storms can cause blackouts, damage GPS signals and harm human health but we can prepare for them with enough warning. Current forecasts are based on several-day-old observations due to the processing time but the researchers found that forecasts produced using near-real-time data still produced reliable predictions. This technique could be used in upcoming space missions such as the European Space Agency's Vigil mission (set to launch in the mid-2020s) to monitor hazardous solar activity.

10

A FOURTH DIMENSION TO VIRTUAL REALITY
A new, wearable virtual reality (VR) interface that allows users to smell odours could be used to augment video games and create four-dimensional films. Researchers from Beihang University, China and the City University of Hong Kong demonstrated the interface with 30 smells, including rosemary, mojito, pancake and durian (below): a fruit so smelly that it's banned on public transport in several Asian countries. The interface comes in two formats: a soft mask that can generate nine odours and one that sits under the nose that can produce two. The interface could also be used to help amnesia patients recall emotional memories.

THE SWEATY FUTURE OF HEALTH MONITORING IS HERE
Introducing the 'sweatainer': a 3D-printed, wearable sweat sensor. But the sweatainer isn't anything to do with monitoring your workouts. Sweat can tell us a lot about our health, according to the researchers who developed it at the University of Hawaii at Mānoa's College of Engineering. Sweat contains information about dehydration and blood sugar levels, as well as serious conditions like cystic fibrosis, diabetes and heart failure. The sweatainer uses sensors to collect and analyse sweat, and, being the first sweat sensor that's not single use, it allows collection of multiple sweat samples. These can either be sent to lab or analysed directly on the device – meaning personal health monitoring could be improved at home.

GETTY IMAGES X3, MOTIAR RAHAMAN, NASA/SOHO, ROXANNE KATE BALANAY/TYLER RAY

PRIMER

THE RISE OF E-FUELS

Synthetic fuels could make transport more sustainable... but at a price

The likes of Porsche and Ferrari are banking on synthetic fuel to ensure their cars are exempt from the EU ban on the sale of new combustion engine vehicles by 2035. Synthetic fuel – or electrofuel (e-fuel) – is a form of petrol made using hydrogen from water and carbon from air. The problem is the electricity that's required to extract these elements. Nevertheless, companies are already producing e-fuel on a small scale, including some in the UK. So will we see e-fuel in petrol stations soon and can we, and the planet, afford to use it? We spoke to Prof Patricia Thornley, Director of the Energy and Bioproducts Research Institute (EBRI) at Aston University, to find out.

WHAT ARE E-FUELS?

E-fuels are synthetic fuels. We create them from the building blocks of carbon dioxide (CO_2) and hydrogen. You can use electrolysis to produce hydrogen and you can pull the CO_2 out of the atmosphere by direct air capture. Combining these produces a hydrocarbon fuel. If you get different mixes of these molecules, then that provides you with different fuels for different purposes: lighter molecules are suitable for, say, an aircraft's ignition fuel, while you'll need heavier molecules for car or marine engines.

HOW ARE THEY DIFFERENT FROM BIOFUEL?

With biofuels (for example, ethanol and biodiesel) you're growing material that contains carbon, hydrogen and oxygen, and trying to convert it into a liquid or gas that you can use. In many ways, that pathway is the same with e-fuels but it's different in that biofuel needs land.

The main advantage of e-fuel is that you're not using plants but the disadvantage is that you're using more energy and this energy still has to come from somewhere.

HOW DOES E-FUEL HELP TO CUT DOWN CARBON EMISSIONS?

If we were to use e-fuel in today's car engines, the carbon emissions that come out of the back of the vehicle will be the same in terms of the amount of CO_2 that is, literally, emitted into the atmosphere. But that's not all we need to think about when we think about carbon. Because if the carbon in the fuel has come from a renewable source – if, for example, it has recently been extracted from the atmosphere – then we're recirculating it back again.

We don't need to worry that we've created a new carbon burden in the atmosphere as it's the perfect circle: those carbon atoms that were in the air have been sucked out by direct air capture, turned into a fuel and then re-released. It's the same with biofuels – they both give you a low-carbon fuel that can actually help us with tackling climate change.

HOW SOON COULD E-FUELS BE AVAILABLE?

We're not yet at the stage where we're producing large enough quantities of e-fuels to be able to roll them out commercially. Realistically, that won't happen until we have an appropriate policy measure in place.

WOULD PETROL STATIONS NEED TO CHANGE TO ACCOMMODATE E-FUELS?

No. In the first place e-fuel mimics existing fuel so we can operate in the existing fuelling infrastructure. Any changes we'd need would be 'upstream' [at points earlier in fuel production process]: if you want significant amounts of e-fuel, then you need to have more renewable electricity in the place where you're going to produce the fuel. The electrical infrastructure would be the thing that has to change if we had a massive increase in e-fuel production in the UK. But you would also need electrolysis plants [where water is separated] to produce hydrogen.

HOW MUCH WOULD E-FUEL COST?

It would currently be much more expensive than other fuels. Because this method of obtaining fuel from a hydrocarbon [an organic compound consisting of hydrogen and carbon] uses electricity – and that process requires electrolysis units, which

e-fuel production is rising in the UK but commercial mass-production will need policy to back it up

SHUTTERSTOCK

cost a lot. To keep the cost down, we can use solar energy to do the electrolysis. Sunlight is free but we still need to get the cost of the solar panels down. Until we reduce the cost of these units, we won't be able to produce much hydrogen from electrolysis.

WHAT ARE THE HIDDEN COSTS?

It's the life cycle cost that we need to be careful about. Electrolysis units use a fair amount of rare earth metals, or what we call 'critical minerals'. We need to be sure that if we want to build lots of these units, then we have enough critical minerals for that to still be sustainable. That's what makes the production of the electrolysis units, and the cost of these fuels, expensive. And then we have to combine the hydrogen and carbon dioxide via catalysts [using substances to increase the rate of the chemical reaction], which use metals too.

All the way along this production chain, we're using Earth's resources. If we use them in a moderate way that's fine but if we get down to limited minerals that's a problem.

Firstly, they're expensive. Secondly, they're often in parts of the world that are geopolitically unstable. And thirdly, we could be depleting Earth's natural resources to the extent that it becomes unsustainable. And there are also social factors to consider in the countries where these are extracted, such as mining conditions. Importantly, we need to make sure this is completely responsible.

E-fuels are a good idea but we need to look at the consequences of their life cycle and the ability of our planet to sustainably supply the metals and materials needed.

ARE E-FUELS SAFE?

Absolutely. We all get on aeroplanes and we trust them! There's a lot of fear around the word 'hydrogen' – people think of the Hindenburg airship disaster. But we've come a long way and the use of hydrogen is common in industrial plants globally. Of course, we must put the appropriate health and safety procedures in place but we know how to and are able to do it.

This fuel could work in many vehicles – including, potentially, rockets. What's the potential for this to make space transport more sustainable?

It's plausible because we're taking those building blocks of carbon dioxide and hydrogen, so we can use chemistry to create just about any fuel we want.

PROF PATRICIA THORNLEY
Patricia develops sustainable bioenergy systems at the Energy and Bioproducts Research Institute.

HEALTH

SEE INSIDE THE MOSQUITO ARENA BUILT TO TEST HOW THE MALARIA-SPREADING BUGS HUNT HUMANS

Welcome to what could be the worst campsite ever – where mozzies are guaranteed

A team of scientists have built an ice-rink-sized arena in Zambia to investigate how mosquitoes find humans to bite from far away. And they've discovered that body odour makes some people more attractive than others.

The study, published in the journal *Current Biology*, is one of the first to test how the *Anopheles gambia* mosquitoes (the most efficient vectors for malaria in Africa) locate human hosts in a 'real-world' setting rather than in a lab.

Over six consecutive nights, 200 mosquitoes were released into the arena, outside which six human volunteers set up small tents. Pipes leading from the tents brought the sleeping participants' smells onto landing pads inside the enclosed arena, where mosquito activity was monitored with infrared cameras.

In the future, the body odours of people more attractive to mosquitoes "could be synthesised to develop better, more attractive baits for mosquito traps," said Alicia Showering, a doctoral candidate at the London School of Hygiene & Tropical Medicine not involved in the research.

"This research has the potential to lead to new tools in the fight against malaria, which could improve the quality of life and health outcomes in areas where the disease is most prevalent."

1

1. An aerial view of the 1,000m³ arena in Choma District, Zambia .

2. Repurposed air-conditioning ducting was used to pump air from each of the six tents around the arena – and the body odours of the sleeping volunteers within them – onto the landing pads inside the arena. The landing pads were warmed to human skin temperature (35°C).

3. One of the six small tents where participants slept. The researchers found that one lucky volunteer had a completely different body odour composition to the others and consistently avoided the mosquitoes' attention.

4. Mosquitoes were released into the netted arena each night and left to find the landing pads on their own.

JULIEN ADAM X4

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COMMENT

WHY SCHRÖDINGER'S CAT IS STILL THE MOST CONTROVERSIAL THOUGHT EXPERIMENT IN SCIENCE

Nearly a century after its formulation, the paradox remains hotly debated among researchers

One of the most important tools in the theoretical physicist's kit is the thought experiment. If you study relativity, quantum mechanics or any area of physics applying to environments or situations in which you cannot (or should not) place yourself, you'll find that you spend a lot more time working through imaginary scenarios than setting up instruments and taking measurements.

Thought experiments pose an imaginary question and work through a logical, 'if/then' sequence to explore what the theory really means. Asking "what has to happen if the theory is true?" is vital for developing intuition and anticipating new applications. In some cases, a thought experiment can reveal the deep philosophical implications of a theory or even present what appears to be an unsolvable paradox.

Probably the most famous thought experiment is Schrödinger's Cat – because it involves (purely hypothetical) carnage and its implications for the nature of reality in a quantum world continue to challenge students and theorists everywhere.

The basic (again, purely hypothetical) setup is this. Imagine you have a radioactive atom that has a 50 per cent chance of nuclear decay in a certain time (let's say, an hour). You put this atom in a box along with a vial of poison and a device that will break the vial if the atom decays. Then, you put a live cat in the box, close the lid and wait an hour before opening it again.

It's straightforward to deduce that since the chance of the atom decaying and releasing the poison is 50 per cent, half the time you'll end up with a living cat and the other half you'll find a dead one.

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

"Before you open the box, the cat is both alive and dead at the same time"

But when Erwin Schrödinger described the thought experiment to Albert Einstein in 1935, he did so to highlight an apparent consequence of quantum theory that seemed to be complete nonsense: the idea that before you open the box, the cat is both alive and dead at the same time.

Ultimately, it comes down to the principle of uncertainty in quantum mechanics. Unlike classical mechanics (the physics of our everyday lives), in quantum mechanics, there seems to be a fundamental uncertainty built into the nature of reality. When you flip a coin (a classical event), it's only 'random' because you can't keep track of all the motions and forces involved. If you could measure everything, you could predict the outcome every time. But in the quantum mechanical version of a coin flip (the radioactive decay) nothing can tell you the outcome before it occurs. As far as you're concerned, until the measurement occurs, the system will act like it's in both states at once: the atom is both decayed and not decayed, in what we call a superposition.

Superposition is a real phenomenon in quantum mechanics and we can use it to our advantage. Quantum computing is built on the idea that a quantum computer bit (or qubit) can be in a superposition of one *and* zero, instead of just one *or* zero, massively increasing the computer's ability to do many complex calculations at once.

In the case of Schrödinger's Cat, the apparently absurd conclusion that the cat is both alive and dead comes from considering the whole apparatus (the atom, the device, the vial and the cat) to be a single quantum system, each element of which exists in a superposition. The atom is and isn't decayed, the device is and isn't triggered, the vial is and isn't broken, and the cat is and isn't alive, until the box is opened.

Whether this conclusion is actually absurd is an open question. What Schrödinger and Einstein concluded was that true, fundamental uncertainty cannot apply to the real world. Today, most physicists accept that uncertainty is real, at least for subatomic particles, but how that uncertainty 'collapses' when a measurement is made is up for debate.

In one interpretation, any measurement that's performed alters reality – though it's usually argued that the device (or, at least, the cat) provides a measurement for that purpose. In another interpretation, the entire Universe duplicates itself every time a quantum coin is flipped and the measurement simply tells you whether you're in the dead-cat or alive-cat universe from now on.

While we can't say how long it'll take us to understand what's going on in the black box of quantum superposition, applications of quantum theory are already bringing us advances, such as quantum computers. In the meantime, thought experiments allow us to follow our curiosity, without running the risk of killing any cats.

ILLUSTRATION: MATT HOLLAND

COMMENT

COULD DELAYING YOUR MENOPAUSE BE BETTER FOR YOUR HEALTH?

The 'change' is a turning point in women's lives that we still don't fully understand

Menopause is when the ovaries stop working, after which ovulation, periods and the production of the hormones oestrogen, progesterone and testosterone ceases, and women can no longer become spontaneously pregnant.

Human women are one of the few species that go through menopause; the only others we know of being female short-toothed whales (belugas, short-finned pilots, orcas and narwhals). Almost all other animals retain the ability to reproduce throughout their lifespan.

Why humans are almost unique in experiencing menopause is not yet fully understood. But, in evolutionary terms, there must be a reason why female humans have developed to stop reproducing and continue to live afterwards.

One theory is the 'grandmother hypothesis', which suggests that older non-reproductive females benefit the group – they can concentrate on seeking food and caring for the babies of younger mothers.

There are also benefits to the individual, including the transition to a stable level of hormones, the ceasing of periods (and the pain and bleeding that goes with them) and no concerns of pregnancy.

In humans, the ovaries are dormant until puberty, like the testes. However, unlike the testes, the ovaries are the fastest ageing tissue of all – ageing at up to five times the rate of other tissue. This is obviously significant, although we don't yet know why. Much research is being done on this, to understand what is happening at a cellular level and why.

It could be that menopause confers biological benefits we haven't yet identified. It's also possible that evolution has made the reason for menopause irrelevant and it now fails to give us any positive effects. In other words, it could be a hangover from our ancestors, which human evolution hasn't caught up with. And, if that's the case, perhaps we could speed up the evolution process and delay menopause through medical intervention – or even prevent it altogether?

Menopause also has negative effects that are linked to the reduction in hormones. Oestrogen reduction, in particular, is known to have a significant negative impact on longer term health, affecting bone, brain, cardiovascular and immune

ILLUSTRATION: ELENA GALOFARO BANSH

> **"It's also possible that evolution has made the reason for menopause irrelevant"**

function, which can lead to a multitude of chronic conditions. Women have a longer lifespan than men, but health is not maintained throughout. The leading causes of death in females in the UK are Alzheimer's and other dementias, and cardiovascular disease.

But these negative effects are lessened in women who go through a late menopause (defined as being after 55 years). They're found to have better bone, brain and heart health, and increased longevity, compared to those who go through menopause earlier. This suggests that delaying menopause could have a significant beneficial impact on long-term health. However, studies show that women with a long exposure to natural oestrogen (women who go through puberty early and/or have a late onset menopause) have a higher risk of breast, uterine and ovarian cancers, which are associated with oestrogen. So, prolonged exposure to oestrogen is not without risk.

But even if delaying menopause was considered a good idea, how exactly would you do it?

First, we must understand what triggers menopause. Research by Jennifer Garrison, an associate professor based at the Buck Institute for Research on Aging in California, suggests that menopause is initiated by signals sent from the brain to the ovaries. Garrison and her colleagues are exploring these signals, which involve neuropeptides that may start the 'switching off' process that leads to menopause.

Although many of the neural pathways in the brain are mapped, the communication between them needs to be better understood so we can pinpoint where these signals come from, how and when they're sent, and what regulates them.

If this is understood, there is the potential to delay or switch off this signalling pathway. Doing so would enable the ovaries to continue to function with no decline in hormone levels, thereby delaying – and possibly preventing – the adverse effects on various organs in females and the ageing process.

There is a growing body of work on the brain-ovary pathway and the ovarian endocrine function. This work is looking at addressing hormonal dysfunction such as in polycystic ovary syndrome, endometriosis and infertility. But its learnings will significantly help our overall understanding of ovarian function, menopause and ageing.

DR MICHELLE GRIFFIN

Michelle is the director of MFG Health Consulting and has almost 20 years' experience as an obstetrician, gynaecologist and clinical leader in the NHS, Public Health England and the World Health Organisation.

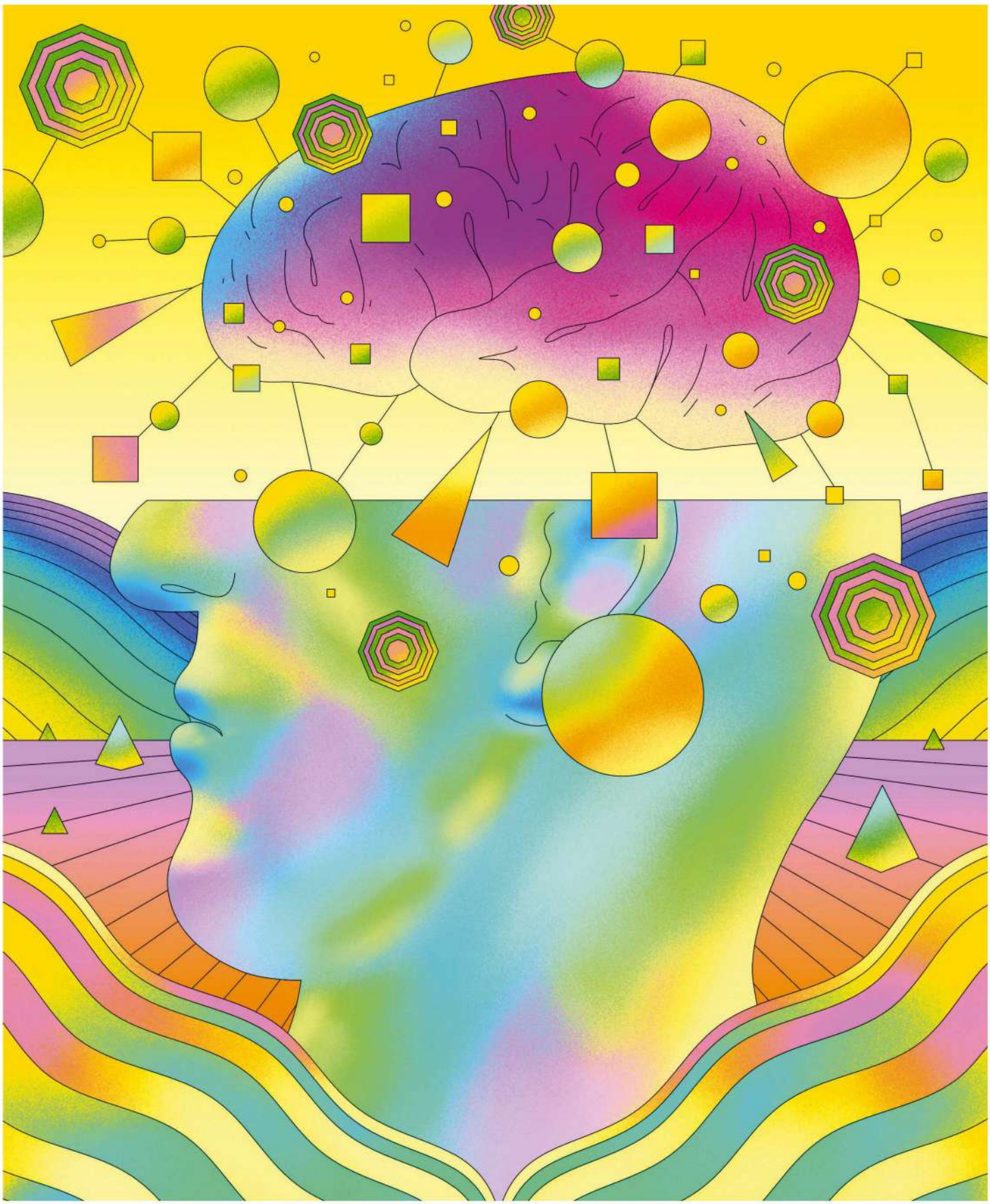


ILLUSTRATION: SCOTT BALMER

COMMENT

THE IDEA THAT WE ONLY USE 10 PER CENT OF OUR BRAINS IS A MYTH THAT NEEDS TO DIE

The myth has been around for over a century and as well as being utter nonsense, it's also potentially dangerous

I was recently asked which scientific 'myth' I'd like to see banished from the public consciousness. Predictably, given the decades I've spent in neuroscience, I had to choose the persistent notion that humans 'only use 10 per cent of our brains'.

We've all heard it, the idea that everything our brains do on a daily basis is handled by just 10 per cent of our grey matter and the rest is… just sitting there, waiting, brimming with untapped potential.

Let's be clear, it's complete nonsense and always has been. Many a scientist has pointed this out but, seemingly, to no avail, as the myth keeps popping up all the time. But here's the thing: it's not just a silly notion, something that leads to eye rolls and shoddy movie plots. It's worse than that. You could even argue that it's actually dangerous.

To begin with, the origins of the myth are unclear. Some contend that it stems from the fact that the original staining methods that made neurons visible under a microscope for the first time only stained a small percentage of the densely packed-together nerve cells. Another possible origin may be that it was widely believed neurons only made up 10 per cent of our brain cells, with the rest being glia, 'support' cells. More recent studies show this to be a huge oversimplification, if not just flat-out wrong. It was also assumed that glia were less 'functional' than is the case.

> "It's like the brain is a busy restaurant with 100 tables but only three waiting staff"

But even though the true origins of the myth remain unclear, one thing we can say for certain is that they go back a long way. Perhaps even as far back as the 19th Century. So that's well over a hundred years of neurological misinformation that's permeated into modern culture. It also reveals the dangers of forming blanket conclusions based on very old research. However accomplished, competent and professional they were, 19th-Century scientists didn't have the tools we have now. Making concrete conclusions based on their work is akin to seeing a small child only being able to lift 10 per cent of the weight of the weekly grocery shop and then proclaiming that "90 per cent of every grocery shop is mysteriously unused."

And here's another thing: the '10 per cent of the brain' myth is wrong in two ways.

To be clear, 100 per cent of the brain is used… for something. We may not know what but it's definitely there for a reason. However, 'used' means 'activated to complete a task' and, in that sense, the idea that we use 10 per cent of our brain is a significant overestimate.

It's important to remember that the brain is an intensely resource-hungry, and very dense, organ, meaning there's not much room for vital blood vessels. According to some studies, this limits our ability to shunt essential resources from one part of the brain to another, to the extent that we can only activate (use), three per cent of our brain at once.

It's like the brain is a busy restaurant with 100 tables but only three waiting staff. The restaurant is all used, or useable, but a maximum of only three tables can be tended to at any one time. So, the '10 per cent' myth is wrong in two, opposing ways.

That leads to another aspect of how the '10 per cent of the brain' myth is wrong: the brain is a wildly demanding organ. It makes up just two per cent of our body weight but uses around 20 per cent of our body's energy, just by being alive.

As such, the brutal logic of evolution means that if we only used 10 per cent of our brains, we'd only have 10 per cent of our brains. Because having a brain as biologically demanding as ours but only using 10 per cent of it, is like bolting a giant supercomputer onto your sports car just to set the clock and play MP3s.

So, the myth is wrong in a variety of ways but still it persists. And that's worrying, because one thing it does do is provide a get-out-of-jail-free card to any hack or charlatan who makes claims that depend on ignorance, or misrepresentation, of how the brain works.

Psychics, mediums, faith healers and others of that ilk make claims that cannot be true according to everything we know about science. And you can provide these people with reams of evidence that prove this conclusively. But if they can say "Ah, but we only use 10 per cent of our brains, so…"

In essence, the 'we only use 10 per cent of our brain' myth provides a huge 'unknown' space in which pseudoscientific/bogus brain-based claims can hide. All established neuroscience lies within the 10 per cent, so logically anything it disagrees with must be from the 90 per cent. And the more people who accept that myth as fact, the more fertile terrain those who depend on brain-based ignorance will have to exploit. And that's, you know… bad. At least I think it is.

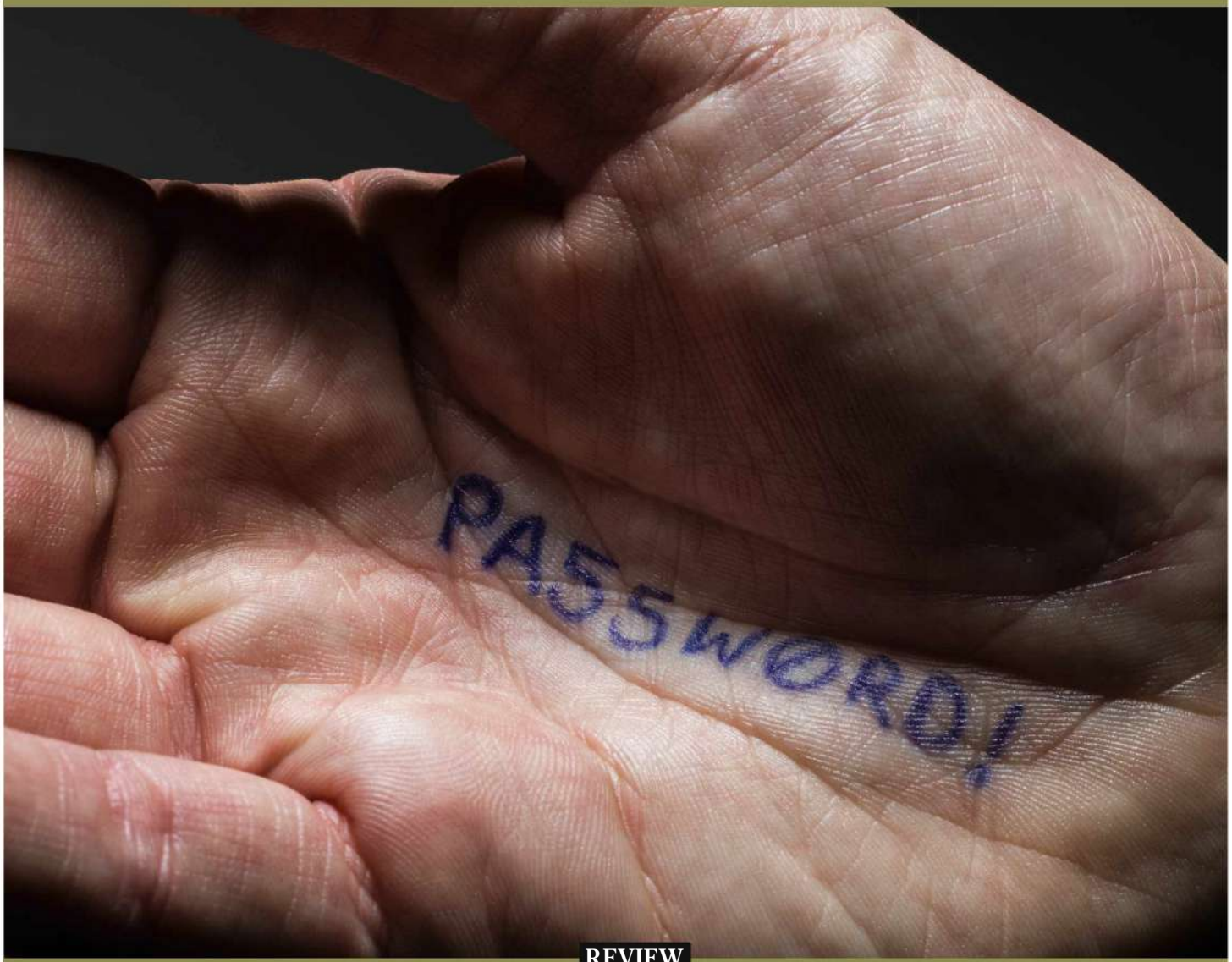
DR DEAN BURNETT

Neuroscientist Dean explores the nature of dreaming in his latest book Emotional Ignorance *(£14.99, Guardian Faber).*

REALITY CHECK

THE SCIENCE BEHIND THE HEADLINES

Passwords | All-female missions | One meal a day



REVIEW

COMPUTER PASSWORDS: IS THERE A BETTER WAY TO SECURE YOUR DEVICES?

Google's new passkey software offers a biometric replacement for old-fashioned passwords. So can we finally forget about having to remember all those sequences of numbers, letters and symbols?

"Security experts prefer methods that perform authentication of your identity instead of just authentication of your device"

BBC *Visit the BBC's* Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

WHAT'S WRONG WITH PASSWORDS?

The very first digital passwords were invented by an MIT professor in the mid 1960s who needed to give multiple users private access to the same giant computer. Passwords soon became ubiquitous in our computers and it's easy to see why – a simple, memorable word is quick and easy to input when you want to gain access to your computer.

But that's also the problem with passwords. A simple, memorable string of characters such as 'password' or '123456' is easy to guess, and when hackers ask their computers to guess millions of passwords a second, even complex words and codes can be broken instantly.

The best way to thwart this kind of hacking is to use long passwords, as the number of combinations (and difficulty of guessing) increases exponentially with length. For example, 'My!_Garden_ShedWith13Daffodils#and17Tulips_Outside' is considerably harder to guess than 'MyPa55wo2d!xxx'.

Nevertheless, it's recommended that you use a different password for every new application, so that if one is exposed by a hacker, none of your others will be at risk. Unfortunately, today this has become unfeasible as everything from Netflix to your bank requires a password – it's not possible for us to remember hundreds of different codes.

Our solution? We write the passwords down, often on sticky-notes stuck to the monitor or keyboard, or on a pad kept in a nearby desk. Alternatively, we use password manager apps that remember everything for us but provide a one-stop-shop for hackers.

But it's not just physical records that make you vulnerable. One of the most common ways for hackers to obtain your passwords is so-called 'social engineering'. It might be as simple as calling a company pretending to be a new employee who forgot their password. Or it might be a scammer who pretends to be your bank and asks you to download special software.

Sometimes 'bait' is left – a USB drive that looks as though it contains something interesting but actually has malware that you inadvertently install on your machine. This will then monitor your device, record your passwords and send them to the fraudsters.

It may even be more brazen: a fraudster who sends a 'scareware' email, claiming they've taken over your computer and that they have videos of you that they intend to post publicly unless you give them what they want.

SO PASSWORDS ARE A WEAK SPOT. DOESN'T TWO-FACTOR AUTHENTICATION SOLVE THAT?

To some extent, yes. But two-factor (or multi-factor) authentication (2FA/MFA) still relies on you remembering the relevant password.

2FA-enabled devices work by asking you for your password before they use another method of identifying you – a text or email, or a request for a response via a dedicated app. The theory is that even if hackers have your password, they'd still be unable to gain access because they'd need your phone or computer.

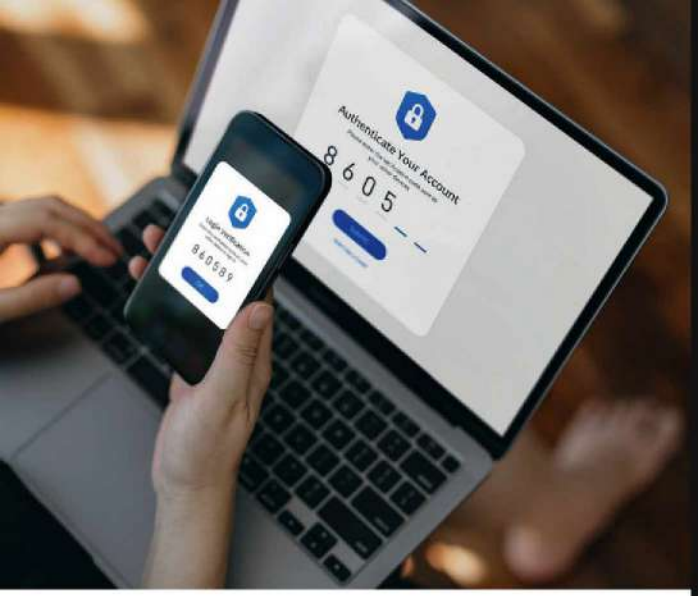
But 2FA is still vulnerable to hackers through various methods. For example simply resetting a password can sometimes bypass the 2FA, or hackers could 'SIM-jack' your SIM card so that texts go to their device instead of yours.

SO WHAT DO THE EXPERTS RECOMMEND?

Security experts prefer methods that perform authentication of your identity instead of just →

BELOW Passkeys rely on biometric information, such as your fingerprint, to grant you access to protected apps and devices

GETTY IMAGES X2



ABOVE Two-factor authentication improves security but is by no means foolproof

→ authenticating your device. This is where biometric passkeys come in. Biometric authentication uses special sensors in your devices to measure features unique to you and uses those as a passkey.

Your fingerprint, 3D facial dimensions, iris, retina and palm vein can all be used. And today's smartphones, laptops and tablets are capable of reading fingerprints and faces, so they can perform accurate biometric authentication.

HOW DO BIOMETRIC PASSKEYS WORK?

When your device knows it's really you, then it has to send that approval securely to the application demanding authentication. Passkeys provide that mechanism. They use cryptographic security to ensure that data transferred between sender and recipient cannot be intercepted and deciphered.

Your phone stores a private cryptographic key and releases a public key to the application. This enables your phone to send a private message to the application that can only be read by that application saying: "the biometric test has been passed." All you needed to do is look at the phone or put your finger on the fingerprint reader.

AND PASSKEYS ARE BETTER BECAUSE...

Once we have biometrics and passkeys, we no longer need passwords. And this looks like the next stage in the evolution of computer security. Google has announced that it's switching from passwords to passkeys, turning off passwords and 2FA altogether for those users who wish to switch.

It's a better solution for everyone: no more passwords to remember, no codes sent to your phone that you have to type in. And should your phone be lost or stolen, it's no problem: the authentication requires your face or your fingerprint. So it won't work for anyone else.

Like all changes, it may take some getting used to. But adoption is likely to be a choice and given the alternatives, it's a big improvement.

by **DR PETER BENTLEY**

Peter is a computer scientist based at University College London and the author of 10 Short Lessons In Artificial Intelligence And Robotics.

ANALYSIS

SPACEFLIGHT: SHOULD THE FIRST CREW TO TRAVEL TO MARS BE ALL-FEMALE?

A new study carried out by the European Space Agency suggests that women may be better suited to space travel

"That's one small step for man, one giant leap for mankind". Neil Armstrong's famous declaration tellingly illustrates that the first generation of Moon landings were a male-dominated affair. Perceptions back then were that women simply did not have 'the right stuff' to make it in space. This was, of course, nonsense.

These days progress has been made and now the world's astronaut corps are much more balanced in terms of gender. But could it be the case that females have the edge when it comes to putting humans back on the Moon, or travelling to Mars and beyond?

A recent study by the European Space Agency's (ESA's) medical team, concluded that "there may be a number of operational advantages to all-female crews [for long-duration missions]." The work considered a theoretical group of astronauts and made estimations of the life support requirements and consumables that such a crew would require. They concluded, not surprisingly, that because females, on average, are smaller and lighter than males, they would need less food and oxygen over the course of a mission.

This is key, as getting stuff – spacecraft, robots, humans and everything needed to sustain them – into space takes large amounts of energy. The laws of physics demand that to orbit a planet, or to escape its gravity and fly to another one, the stuff needs to accelerate to very high speeds. The more stuff, or mass, you want to get into Earth orbit, or to the Moon or Mars, the larger the rocket you need.

So, if women are lighter, and eat less, should the first crew to fly to Mars be all-female? The ESA study was a follow-up to an earlier paper by the same researchers that considered a theoretical all-male crew.

Separating the sexes, or 'sex disaggregation', in research is a good thing, as there are biological differences between them, and understanding these differences results in better informed decisions. But as the journalist and author Angela Saini, who has researched the impacts of sex-based research, says: "There is actually no real-life 'default' male – every man is different from the next, just like every woman is. While it's great that women have been studied, the more important takeaway is that individual astronauts should obviously be considered."

GETTY IMAGES, NASA/JSC

“Because females, on average, are smaller and lighter than males, they would need less food and oxygen over the course of a mission”

Getting humans to Mars and back safely is a huge challenge. A round trip would take around two years, with the crew having to endure a harsh radiation environment, as they’re bombarded by solar wind. Also, as they got further from Earth, communication delays would increase, with messages taking minutes to travel one way, rendering normal conversations with anyone back on Earth impossible.

Once on the Red Planet, after nine months in transit and living in a weightless environment, the crew would have to be physically and mentally capable of living on the surface of Mars before making the return trip home. Solving the challenges of keeping astronauts safe and well will require a staggering number of considerations.

ABOVE Kristina Koch is part of the crew that will be making humanity’s next flight to the Moon

The ESA studies showed that, just as on Earth, the resources needed to sustain a crew when they exercise are higher than at rest. But exercise is vital to ensure that astronauts’ bones and muscles are strong enough for them to function when they land.

HIFIm is a new exercise device invented by John Kennett, director of Physical Mind London, that might hold the answer. Smaller and lighter than current exercise equipment, HIFIm workouts are carried out on the bench-like device and are based around jumping movements, rather than running or cycling, and could revolutionise in-space exercise programmes.

Kennett says: “ESA has proven jumping just four to six minutes a day mitigates the effects of being in microgravity. This means that HIFIm could reduce the →

ABOVE Astronauts need a wide range of skills, including the ability to work well as part of a team

→ time astronauts need to exercise by over 80 per cent." So using the new device could also reduce the resources the astronauts need and lessen the payload any rocket would have to carry.

As well as staying fit and healthy individually, any crew must also function well collectively. While humans haven't yet travelled to Mars, research has been carried out into how people function in confined, isolated environments for long periods of time and it shows that a diverse crew is key to success.

Susan Charlesworth, director of Oxford Human Performance, and a specialist in human factors for space missions, says: "Men and women often have different, complementary leadership and conflict management styles that temper one another, leading to better cohesion over extended periods. A crew that is diverse in many characteristics maximises its likelihood of successful teamworking."

Overcoming these extreme environments and challenges is also part of why human spaceflight can be inspirational to so many people, and the first mission to Mars will surely captivate imaginations. In order for it to reach the widest possible audience, however, inclusivity is vital.

Saini says: "One of the mistakes of earlier eras was to assume that all women were incapable of going into space. It would be just as damaging to assume that all men were unsuitable. I would hate for young boys to feel they couldn't dream of being astronauts, just as I hate that young girls were ever made to feel that way."

Space agencies spend a lot of time and effort selecting their astronauts, finding people with the right mix of skill and personality needed to thrive in space. These astronauts are then carefully combined into crews, taking account of the specific demands of any given mission.

The first journey to Mars will be risky, arduous and daunting. The crew that take that step will be painstakingly chosen and will most certainly have the right stuff to undertake what will be a monumental leap for humankind, whatever their gender.

by **LIBBY JACKSON** *(@LibbyJackson__)*
Libby is an expert on spaceflight and author of Space Explorers: 25 Extraordinary Stories Of Space Exploration And Adventure

COMMENT

ONE MEAL A DAY: COULD IT WORK FOR WEIGHT LOSS?

Is eating just once a day the secret to staying trim or is it just restrictive eating?

Society has an ongoing fascination with the constantly shifting trends in celebrity diets. The one meal a day (or OMAD) diet is one such trend, reportedly championed by the likes of Bruce Springsteen, Coldplay frontman Chris Martin, football pundit Gary Lineker and even the prime minister, Rishi Sunak. But does the science back up the claims?

OMAD is an extreme fasting diet. As the name suggests it involves eating just one big meal a day, with fasting, or very minimal eating, in between. The key focus of this kind of diet is weight control and simplicity.

There are many celebrity anecdotes surrounding OMAD and from an evolutionary point of view, it can seem reasonable to suggest that human biology is better suited to less frequent meals. This theory is based on our ancestors often experiencing cycles of feasting and fasting rather than the relatively modern construct of three meals a day. But while fasting itself isn't new, the research on its health impacts is still in its infancy and there are very few studies on OMAD and the evidence supporting other more periodic types of fasting can't necessarily be extrapolated into extreme fasting.

One trial exists on OMAD, where participants ate either one meal a day or three meals per day, with their calorie intakes tailored to theoretically maintain their current weight. When on one meal per day they reduced body weight and fat levels, and displayed features of "metabolic flexibility" (changes in measures of how fats and carbohydrates are metabolised). But participants also experienced a loss of muscle and bone mass. This highlights that a focus on weight loss alone can miss the potential downsides of this kind of diet.

Importantly, the results of this study can't be applied to everyone. Only relatively healthy people were included and no one with obesity, cardiovascular disease, diabetes, mental disorders, eating disorders or other metabolic conditions was allowed to participate. Furthermore, the trial was small and short, with just 11 participants following the diet for 11 days.

One of the claims made by supporters of OMAD and other fasting diets is that you can eat whatever

GETTY IMAGES, ALAMY

"Celebrity lifestyles are enticing but this is precisely because they're so unlike our own"

ABOVE
Cramming all the nutrients necessary for good health into a single – tasty and manageable – meal is difficult

you want for the one meal you are eating each day. But if all nutrients for good health are to be obtained in just one meal, it needs to be nutrient dense and balanced to ensure you get a sufficient intake of fibre, protein, vitamins and minerals. Supplements may help avoid nutritional deficits but they lack the complexity of foods, which means other healthy essentials, such as bioactive compounds, may be missed. This means there may be longer-term consequences for bone, digestive and other elements of your health, despite the easy-to-measure and instantly gratifying weight loss.

Indeed, when meal frequency has been studied in larger groups (over 24,000 people) for longer periods (about 15 years), eating just one meal a day was linked to a higher risk of death from any cause, and from cardiovascular diseases. Observational studies like this can't show the cause of the relationship but the results were found even when factors like age, gender, race, ethnicity, education, income, smoking, alcohol intake, physical activity, energy intake, food insecurity, snacking habits and health at the start of the study were taken into account.

It's also important to consider the other roles that food plays in our lives. Food is more than just calories and nutrition. It's part of our culture, society, celebrations and enjoyment of life. The social and emotional consequences of OMAD have not been documented but there is data showing that restrictive diets can have significant psychological consequences.

Reporting on celebrity trends is part of how pseudoscience and fake news spread in the health and beauty industry. There may be limited resources to fully fact-check the articles and few details mentioned of how stringently celebrities are truly following these diets. Plus, their true health, beyond their appearance, isn't known. Remember: any information is being shared selectively and facts can be omitted for the sake of the story. As long as stories on celebrity diets remain a good source of 'clicks', they'll be fraught with clickbait – and extremes like OMAD give us just that.

The average person considering OMAD, or any other celebrity diet, does not have the same luxuries and support structures that celebrities do: the nutritionists, the nannies and the other assorted assistants, for example. So, we don't all have the same capacity to deal with the potential side effects that come with extreme fasting, which can include nausea, dizziness, low energy, irritability and constipation. Celebrity lifestyles are enticing but this is precisely because they're so unlike our own.

Celebrities give us many great things, like films, music, art and sports, but they're not the most reliable source of nutrition information. Instead, official dietary guidelines, based on the complete body of nutrition science knowledge should be used for general advice, and qualified health professionals such as dietitians should be consulted for your individual needs. **SF**

by **DR EMMA BECKET**
Emma is a senior lecturer in the School of Environmental & Life Sciences at the University of Newcastle (Central Coast) and senior food & nutrition scientist at Nutrition Research Australia

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

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NEW TECH
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Our pick of this month's greatest new gadgets **p48**

Can you tell a human-made piece of art from AI-generated art? The clues are in the details p44

SHUTTERSTOCK

22% OF PEOPLE WITH A SMART DOORBELL SAID THEY BOUGHT IT FOR A GREATER SENSE OF SECURITY

$2.7 bn
THE CURRENT VALUE OF THE SMART DOORBELL MARKET

1/5 OF BRITS HAVE A SMART VIDEO DOORBELL

INTERVIEW

AI art is everywhere but it can never compete with human creativity

Alex Hughes speaks to **Prof Ahmed Elgammal**, an expert in artificial intelligence to learn more about the rise of art made by AI

As artificial intelligence (AI) improves, artists are finding themselves in unprecedented territory. Realistic images are being made in seconds; millions of them are created each day; and the images are being entered into and winning art competitions. But none of them are being made by humans.

We spoke to Ahmed Elgammal a professor of computer science at Rutgers University to find out about the rise of AI art and what it means for human creativity in the digital era.

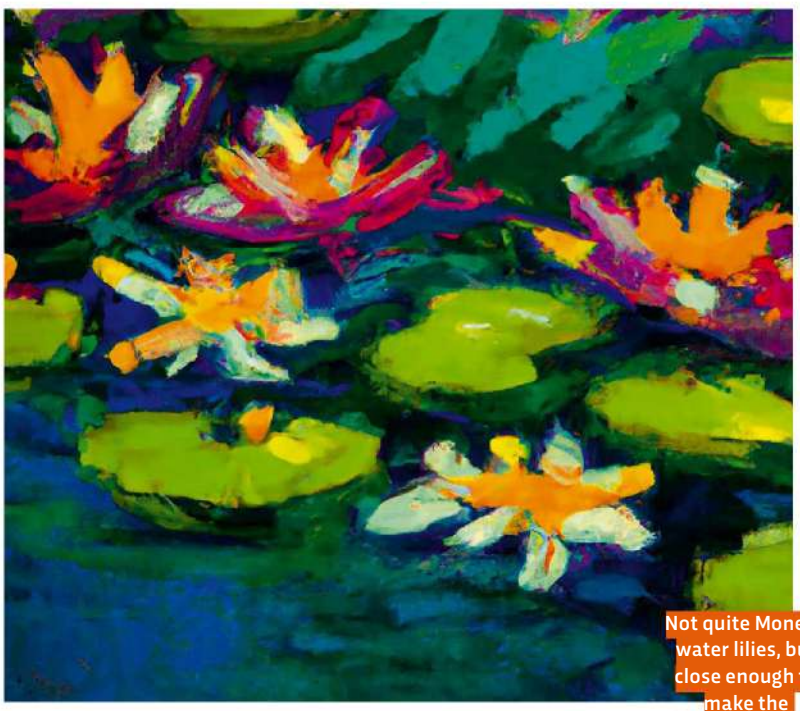
HOW DO AI IMAGE GENERATORS WORK?

Five years ago, there was an advancement in AI known as Generative Adversarial Networks (GANs). It took images and tried to generate similar results. Give it images of cats and it would return completely new versions to match. This was revolutionary and many artists started using it. Then came a newer generation that used text to generate images to give more control over what was being generated. This worked by training the model on lots of images and their accompanying text caption to understand how the words relate to the images. So in an image of a bird on a tree, the AI guesses where the tree and bird are and the network tells it if it's correct. By doing that for billions of images, the AI figures out what words relate to what images.

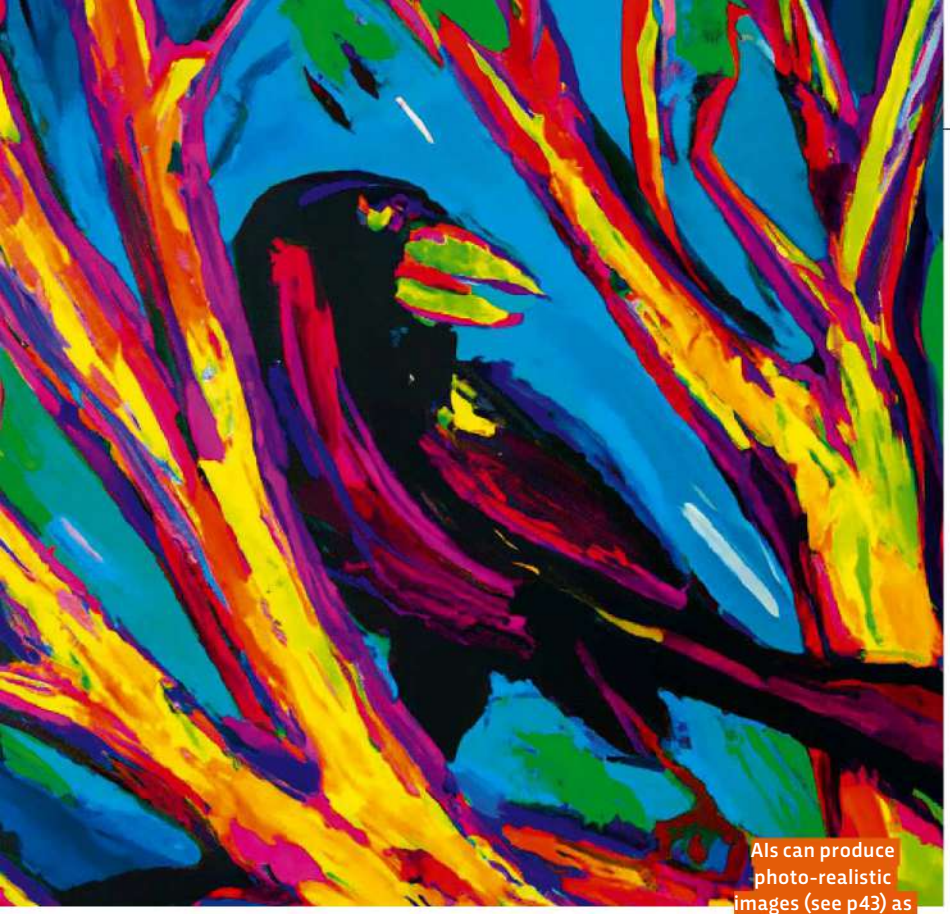
WHY DO THESE AI MODELS STRUGGLE WITH COMPLICATED SHAPES?

These AIs do struggle with small details. They'll have a hard time generating something small because they're trained to optimise through lost function, which is a criteria that encourages it to optimise a whole image, trying to get the majority of it correct. The AI neglects the small details that we, as humans, are tuned to catch – a hand with four fingers or a three-legged person, for example. To the AI, there's no difference between this and any other small details in the background.

Asking an AI for 'impressionist water lilies' leaves a lot of room for interpretation



Not quite Monet's water lilies, but close enough to make the intention clear



AIs can produce photo-realistic images (see p43) as well as more interpretative results

HOW MUCH ENERGY DOES IT TAKE TO MAKE THESE SORTS OF IMAGES?

The training process for these models requires a lot of energy. You need to run them on graphical processing units (GPUs) for weeks while they process billions of images. And after that you then need to rewrite them many times over in order to optimise the process. But even after training the models, they need to be running constantly on a GPU with millions of processors and these are very energy consuming devices. Having them running for the lengths of time required has a significant energy consumption and environmental impacts.

THESE MODELS LEARN FROM THE INTERNET AND SUFFER FROM THE BIASES AND MISINFORMATION THEY LEARN THERE. SHOULD THERE BE A DESIGNATED LIST OF INFORMATION, OR SHOULD THE AIS HAVE ACCESS TO EVERYTHING?

How can we control the data given to an AI? There are different opinions on everything from politics to religion, lifestyle and everything in-between. We can't censor the data it's given to support certain voices. The AI naturally must reflect all opinions and viewpoints in the world. This will come with a lot of misinformation but that is the world we live in. The same way we look at feeds in social media. You filter out or guess that this is false information, or this is true information. Right now, AI has no way to tell fact from fiction, everything is just words and once we start talking about facts, that's a big problem. What are the correct facts and opinions?

THERE AREN'T MANY LAWS IN THIS FIELD, DOES THIS NEED TO CHANGE, ESPECIALLY AROUND COPYRIGHT?

The copyright problem comes with the current generation of imagery tools that are mainly trained on billions of images. However, this wasn't an issue a couple of years ago, when artists used to have to use AI through certain models that were trained using the artist's own images. The copyright issue comes with the use of millions of images taken from the internet without consent of the artist. The problem is, while it is unethical, it isn't necessarily breaking any copyright laws. It's making transformative versions of the image, not a direct derivative so under any copyright law this would not be a problem. We're going to have to remind everybody that this is not the way it's supposed to be. You can use AI with your own images, without stealing other people's work.

CAN AI LEARN THE CREATIVITY AND EMOTION REQUIRED TO MAKE GREAT ART?

The current generation of AI is limited to copying the work of humans. It must be controlled largely by people to create something useful. It's a great tool but not something that can be creative itself. We must be conscious about what's happening in the world and have an opinion to create real art. The AIs simply doen't have this. A couple of years ago, we used AI in a project to generate Beethoven's 10th Symphony. We trained these AIs on lots of classical music and then they looked at the sketches that Beethoven left for the symphony to generate compilations of these notes. That was a great example of AI as a tool but it uses no creativity. This is what is happening in the world right now with AI. It's a creative process that's mainly human and AI is following the rules to generate content for them.

"AI NEGLECTS THE SMALL DETAILS THAT WE, AS HUMANS, ARE TRAINED TO CATCH, A HAND WITH FOUR FINGERS, FOR EXAMPLE"

IS AI JUST THE LATEST ART MOVEMENT, SIMILAR TO IMPRESSIONISM OR MODERNISM?

In the last five years we have seen this movement, but I think it has ended really. The early artists had specific aesthetics in their work that were uncanny and unhuman like. It had a specific look and style, but I think now it's all becoming more photorealistic. Very good for realistic images but it's lost this ability to be surprising and uncanny and have the surreal effects. I think that era has gone. It's more of a tool for everybody to generate a photo-realistic image, a graphic design and logo, not a unique piece of art.

SHUTTERSTOCK IMAGES X3

Five of the best video doorbells

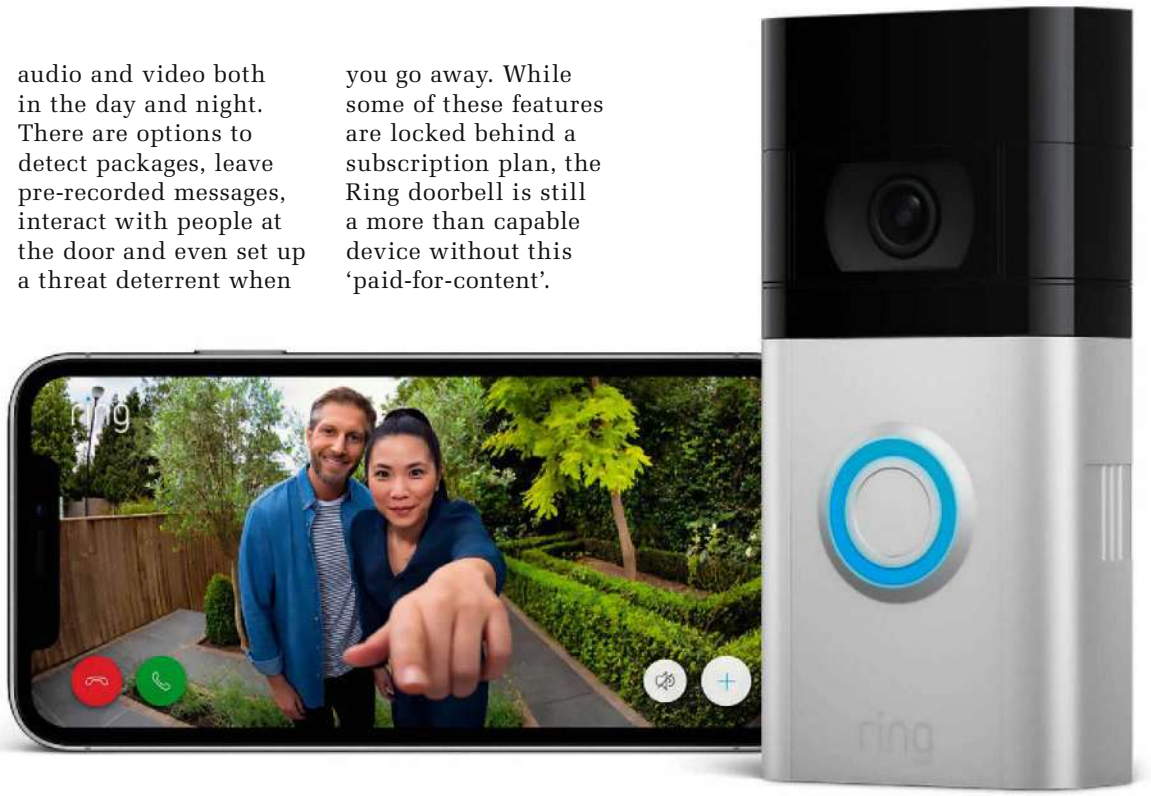
These devices promise to revolutionise the way you collect packages, keep your home safe and even how you interact with your postie and friends. The *BBC Science Focus* team picks their faves

Ring Video Doorbell 4

£139.99, en-uk.ring.com

Ring (owned by Amazon) has been making doorbells for a decade now and the Ring Doorbell 4 is its most recent model. Compared to brands like Google Nest or Arlo, the Ring doorbell isn't the most aesthetic option, offering as it does a purely utilitarian design.

However, what you lose in design, you gain in a long list of features. The Ring has a fantastic battery life, lasting for up to six months at a time from an 8-hour charge. Equally, the camera produces clear audio and video both in the day and night. There are options to detect packages, leave pre-recorded messages, interact with people at the door and even set up a threat deterrent when you go away. While some of these features are locked behind a subscription plan, the Ring doorbell is still a more than capable device without this 'paid-for-content'.



Google Nest Pro Doorbell

£179.99, Store.google.com

The Google Nest Pro Doorbell features a 145° field-of-view, streams in 1600p HD-resolution video and displays footage in a 3:4 aspect ratio, ideal for viewing on a smartphone held vertically.

Although it has a very slight fish-eye effect, the video is crisp and doesn't glitch or lag, as people move in and out of shot. Installation is, for the most part, a piece of cake. It's only the final stage that requires serious wrangling to get it into position. For this reason alone, it's worth wiring into an existing door chime to save the hassle of wrestling it on and off the bracket when it comes time to charge it.

And while it's not the cheapest option on the market, you are compensated for the extra cash by the fact that you don't need to shell out on a subscription package.

Eufy S330 Video Doorbell

£229, uk.eufy.com

Intimidating, innovative, yet far from refined, Eufy's S330 is the Jack Bauer of video doorbells. With two wide-field cameras that reveal who is knocking at your door and whether any packages have been left on your doorstep, this device excels as a home security system. But while it completes this core mission with ease, the S330 also comes with plenty of hidden baggage.

If you live on a quiet road, or your door is far from the pavement, you'll likely take full advantage of the S330's best features: its ability to ping your phone when someone approaches. But those on a busy street may have to disable this capability to avoid constant notifications.

Considering other niggling flaws, notably the lag in video and audio to your phone, it's easy to gawp at this doorbell's price tag. But, unlike some others, you don't need a subscription to access all features.

Arlo Essential Doorbell

£179.99, arlo.com

Simple, quick and offering great picture and sound quality, this is a solid choice for a video doorbell.

The fish-eye lens paired with a square picture resolution means you get a crisp, wide field-of-view. The slim footprint and smart design will make it a welcome addition to any front door. The app is just as well designed and easy to use and Arlo says the doorbell will run for six months before it needs recharging.

It works like a button that rings your phone. The call connection is clear and almost completely lag-free. If someone approaches the house without pressing the doorbell, a motion sensor will detect their presence and send you a notification. Spot this quickly, and you can tune into the camera's live stream and speak to them through the speaker.

Like most smart doorbells some of the device's best features are locked behind a subscription, though.

EZVIZ DB2 Doorbell

£139.99, EZVIZ.com

The EZVIZ DB2 doorbell is best for homeowners who don't live in busy places: the set-up makes it a poor choice for renters and the sensitivity is so fine-tuned, that in a city you could be alerted every time someone walks past your door.

If you want a smart doorbell to be able to answer the door quickly and easily when you're not at home, the security features on the EZVIZ may get in the way. But if security is what you're after, the EZVIZ offers a wide range of features that can help you feel safer, including voice masking as well as good audio and visual monitoring outside the house.

The EZVIZ DB2 sits at the lower end of the smart doorbell price spectrum and provides the basic services well, although you'll have to customise the settings to make sure it works well with where you live.

Ideas we like...

Our pick of the month's smartest tech

↓

...Headphones built to last

No matter what they're made of, over-ear headphones just don't seem to last. Through all the drops, knocks and times they've been forgotten and sat on, every good pair of headphones eventually ends up in headphone heaven. Fairphone, a brand known for its sustainability, is looking to fix this with the XL headphones. All the parts are detachable and replaceable, with parts available to buy directly from the brand. The XLs are made using sustainable materials and the good news is, they also offer the high-end audio specs you'd expect from £200 headphones.

Fairphone XL headphones
Shop.fairphone.com, £219

...A drone for master filmmakers

Got £13K lying around? The Inspire 3 could fall into your budget. The third iteration of DJI's pro film-making drone comes with a full-frame 8K camera (plus a suite of eight additional cameras to sense its surroundings, one of which is a night-vision FPV), lighting fast movement and a huge battery life. All this barely scratches the surface of the DJI Inspire 3 feature list. It's essentially the perfect film-makers toy... if you can afford it.

DJI Inspire 3
£13,419, store.dji.com

...Creating water from nothing

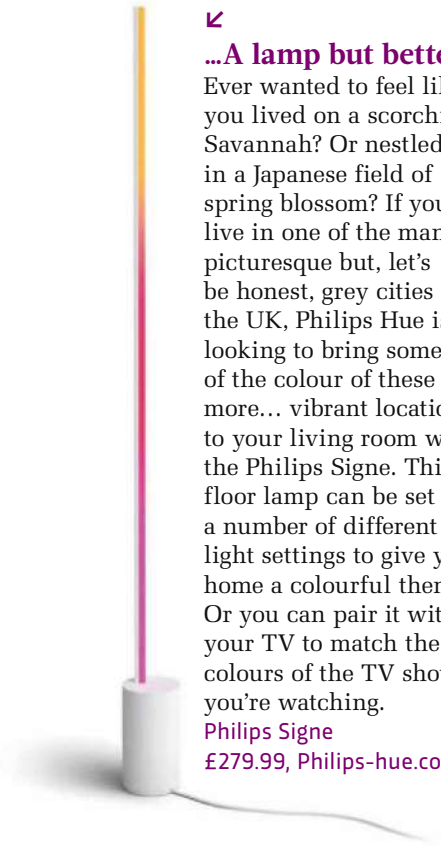
Drawing water out of the atmosphere may not be anything new but that doesn't mean this water filter isn't interesting. The Spout uses a six-stage filtration process that can produce up to 2.5 gallons of clean water from thin air. Its filtration system catches contaminants including smoke, mould spores and allergens. You gain clean, drinkable water but lose a lot of money paying for the unit and the filters.

Spout Water
Spoutwater.com, $799

...A thinner foldable smartphone

Smartphone companies seem set on making foldable phones the next big thing. Following in Samsung's footsteps, Google has released its own foldable device with the big selling point being how thin it is. It performs like a top-tier smartphone with a powerful battery and processor, takes fantastic photos and is optimised for most apps to work with the folding design. It's ideal for fans of... folding smartphones but costs £1,749.

Google Pixel Fold
Store.Google.com, £1749



...A lamp but better

Ever wanted to feel like you lived on a scorching Savannah? Or nestled in a Japanese field of spring blossom? If you live in one of the many picturesque but, let's be honest, grey cities of the UK, Philips Hue is looking to bring some of the colour of these more... vibrant locations to your living room with the Philips Signe. This floor lamp can be set to a number of different light settings to give your home a colourful theme. Or you can pair it with your TV to match the colours of the TV show you're watching.

Philips Signe
£279.99, Philips-hue.com

IDEAS WE DON'T LIKE...

...A SMARTPHONE THAT YOU CAN'T SEE

As part of the barrage of artificial-intelligence powered technology, one brand has proposed a new smartphone experience fuelled entirely by an AI assistant. So how will it work? Well, there won't even be a phone, just a camera that scans your environment, a speaker and a projector that creates a display on your hand. It could make calls, take photos, translate a sentence and read emails. It's intriguing, sure. But like all of these concept ideas, the end result is usually unbelievably expensive, excessively complicated and full of painful quirks and problems that will leave you wishing for a good old smartphone.

Humane phone
£TBC, Humane.com

...A RELAXING SHOCK COLLAR FOR HUMANS

Have you ever watched a dog get hit by a high voltage from a shock collar and thought 'I bet that's relaxing!' No? Neither have we and yet it seems to be the thought process behind the 'Pulsetto'. The team behind the Pulsetto device (above) that sends shocks through your neck to activate the parasympathetic nervous system (a set of nerves that helps you relax) claims it can reduce stress and anxiety, make you calmer and help aid optimal sleep. It's an intriguing offer but somehow random electric jolts throughout the day doesn't sound all too peaceful.

Pulsetto
Pulsetto.tech, $389

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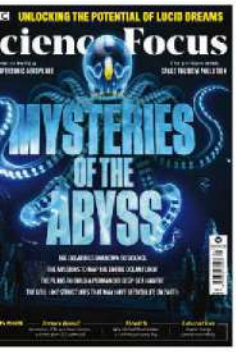


MATTER MADE MAGIC

WELCOME TO THE WONDERFUL WORLD OF PROGRAMMABLE MATERIALS. FROM SELF-ASSEMBLING STRUCTURES TO FUTURISTIC FABRICS, TAKE A PEEK AT THE SHAPE OF THINGS TO COME...

Words: HAYLEY BENNETT

ICD UNIVERSITY OF STUTTGART

ALGORITHMIC ART

Nature takes advantage of the way that wood responds to its environment. We see this when a pine cone falls from a tree and its scales begin to peel open as it dries out, allowing it to release its seeds. It's a result of the wood's hygroscopicity – its ability to take up and release moisture – and the predictable change in shape that it undergoes when this happens.

But such shape-shifting behaviour can also be harnessed by humans. Based on an in-depth understanding of how the moisture content and grain direction of wood affects its shape, German architects programmed this 'climate-responsive' wooden exhibit to open the bud-like structures on its surface in response to rising humidity levels. The humidity inside its glass housing at the Centre Pompidou art museum in Paris, is tuned to reflect outdoor conditions, so the installation acts as a virtual connection to the city outside.

"The model opens and closes in response to climate changes with absolutely no need for any technical equipment or energy," says Professor Achim Menges, director of the University of Stuttgart's Institute for Computational Design and Construction. "Here, the natural material itself is the machine."

MAGNETIC MANOEUVRES ↓

Stuff that sticks together in a preordained way could help with many self-assembly tasks here on Earth but in space, it could be really useful. As PhD student at the Massachusetts Institute of Technology, Martin Nisser (pictured below, centre), explains, "Applications could range from assembling structures from constituent parts in orbit, to helping with docking manoeuvres, to selectively bonding objects like tools to a spacecraft's interior walls."

Nisser's team created 'voxels' – magnetic cubes that can self-assemble, like pieces of a 3D puzzle, and took them on a parabolic flight to watch them in zero-g. The cubes are picky, attracting only their neighbours in the 'puzzle' and repelling others. This is achieved by the magnetic patterning of each cube, which is encoded in an 8 x 8 grid on every face, meaning that the number of unique permutations per cube reaches 20 digits. On Earth, researchers put the voxels in water to keep them moving to find their neighbours, but in space they need a push.

FLEXIBLE FLATPACK →

Programmable design isn't just for space-age applications. We can use it in our homes too, as this second project from the University of Stuttgart and furniture spin-off Hylo Tech illustrates. Benefitting from the same moisture-responsive behaviour as the climate-responsive art exhibit (see page 52), these wooden chairs are delivered in 3cm-thick flatpacks but bend as they dry out to produce stylish, standard-height seating. It's a new concept in flat-pack furniture, as Prof Menges explains: "One in which the shaping is embedded directly within the material itself, leading to a simple and effortless assembly."

As fresh timber has a naturally high moisture content, woodworkers use computer simulations to inform how they retain the right amount of moisture. With the correct fibre direction, they can ensure the cut pieces deform perfectly as their moisture content drops. The chairs are then sealed to prevent them from 'actuating' before they are delivered.

STEVE BOXALL/MIT, ICD UNIVERSITY OF STUTTGART X5

MATERIAL BALANCE RESEARCH GROUP

NOT JUST KNITTING

Knitted textiles have, in a sense, always been programmable – variations in stitch types, tension, and yarn colour and weight can be combined to create different textiles with wide-ranging functions. Now the art of 'computational knitting' is opening up new possibilities, including textiles with architectural features like the peaks in this image, by helping to optimise the programming of knitting machines.

"Since each fabric piece may contain hundreds of thousands of loops, programming becomes complex," says PhD student Maria Anishchenko. She works with the Material Balance Research Group in Milan, Italy, where researchers are attempting to use computer software to 3D model and preview the results of their knitting designs. These can then be digitally tested, before being realised in yarn.

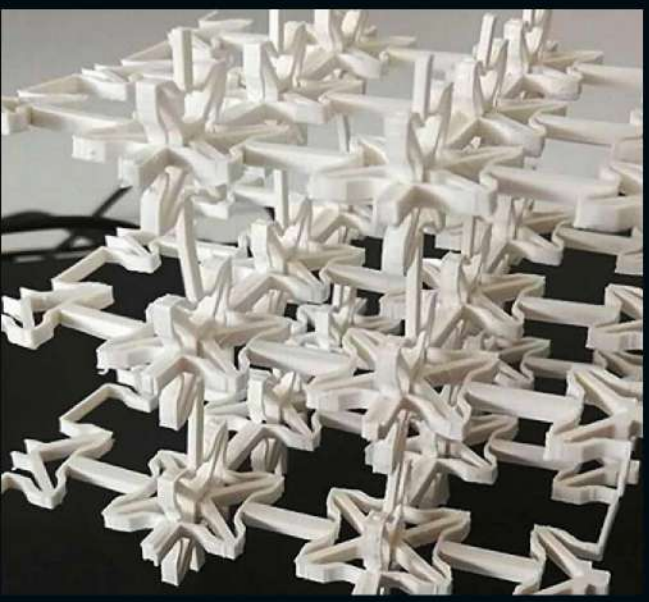
DURAJ-THATTE ET AL, NATURE COMMUNICATIONS, MIT MEDIA LAB, FRAUNHOFER INSTITUTE

LIVING INK ↑

3D printing has made it possible to translate digital designs into material objects and products that are printed layer by layer. But it's not just inert plastic, metal and ceramic products that can be printed. The tiny, jelly-like structures above were printed in microbial ink – a gel made of bacterial proteins and seeded with genetically engineered *E. coli* bacteria. In this sense, it's a living material that, through genetic modification, can be programmed with useful functions like releasing drugs or cleaning up harmful materials. Researchers at Harvard, and Northeastern Universities in Boston, showed they could genetically program the bugs in their bio-ink to release the anticancer drug Azurin (a bacterial protein), when prompted by a chemical signal. It could also be useful for "incorporating living cells into structural building materials".

GETTING PUMPED →

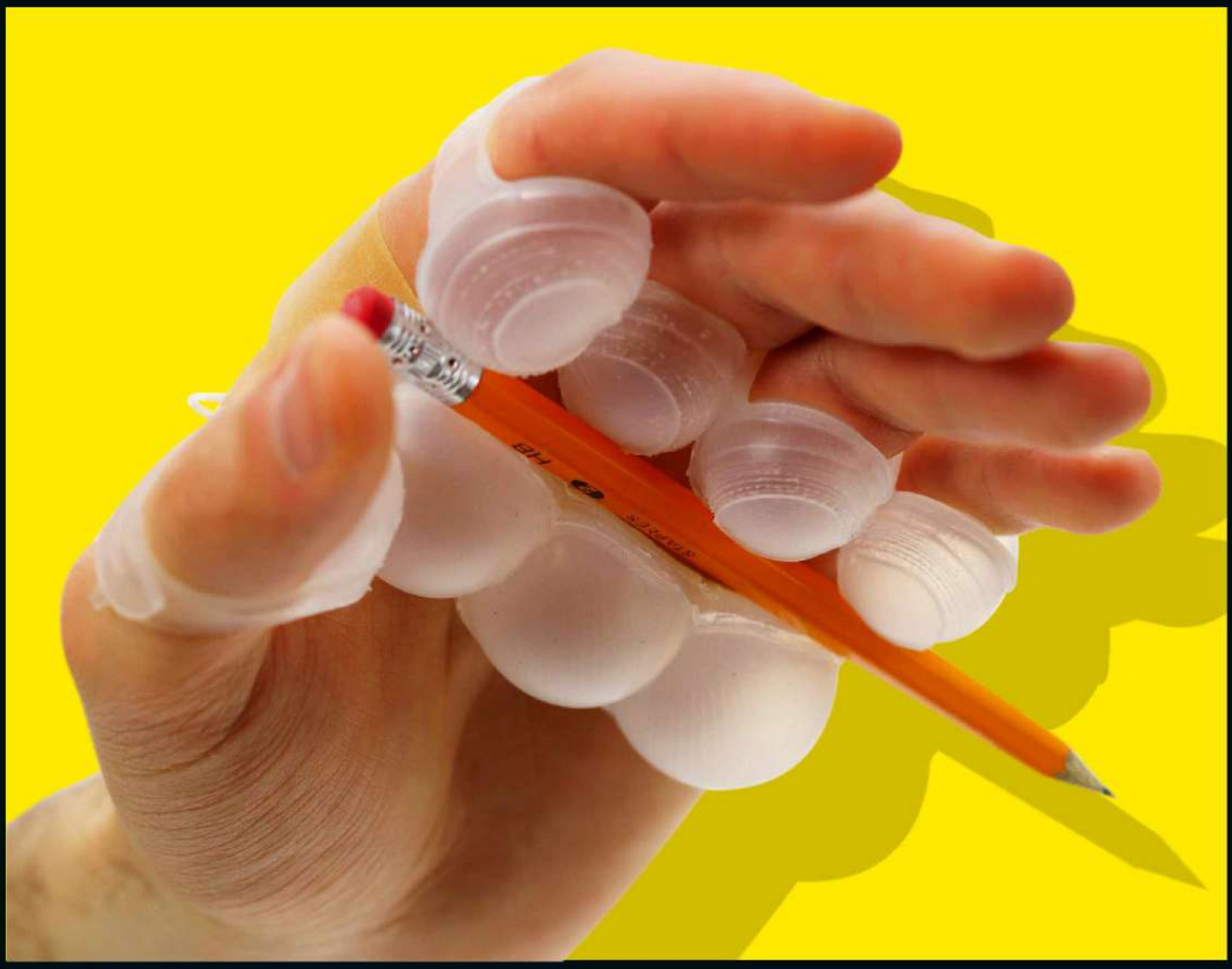
Soft robotics have endless applications, from technologies for people with limited mobility, to more playful uses, such as interactive toys and haptic technologies. But the complex programming they require can often slow down the realisation of these projects. That's why Ali Shtarbanov, a researcher at the Massachusetts Institute of Technology Media Lab, created FlowIO – a platform that people can use to develop soft robotics projects with a minimal need for computer code. Users build their devices using pump systems, which can be controlled by software that's easy to customise. The pumps are used to raise or lower pressure within a soft material to produce an action, such as lifting an object. Shtarbanov has even used his system to produce a hand gadget that could beef up the gripping power of people with arthritis.



ON REPEAT ←

One way to program a material is to alter the base material itself, which is possible using plastics with finely tuneable compositions. Another way is to build them from repeating units at the microscale, or tiny 'cells', like the ones in this 3D-printed 'metamaterial' made by researchers from six German research institutes in the Fraunhofer Cluster of Excellence in Programmable Materials. The size of each cell can be controlled to form a microstructure that reacts in a predictable way. Pressing on a mattress made with such cells, for example, could trigger a change in the softness of the material, which could allow carers to adjust mattresses to prevent bedsores in patients who can't turn themselves. The possibilities for using these metamaterials extends further to pollution-trapping filters with programmable pores. SF

by HAYLEY BENNETT
(@gingerbreadlady)
Hayley is a Bristol-based science writer and editor.



MAKING

How do you study a gigantic mammal that migrates over thousands of miles and spends most of its time underwater? Here's how the latest tech is shaping the future of whale conservation

by JAMES FAIR

On a calm, cold afternoon in early March, in Neko Harbour on the west coast of the Antarctic Peninsula, a humpback whale is making a series of moves that – to me, at the time – have no obvious purpose.

First, the humpback raises one of its outsized pectoral fins – which can reach up to 5m in length, longer than a typical estate car – as if asking for permission to speak in class, before diving and resurfacing. Then it raises the fin again, carrying on like this for another 15 minutes.

Chris Johnson, oceans science manager for WWF-Australia, is watching from a nearby boat and releases a drone equipped with a video camera. The footage transforms what appears from sea level

WAVES

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to be a set of random exercises into a stunning performance as choreographed as any ballet.

As it turns out, the pectoral fin is being used as a rudder to steer the humpback in a tight circle while it blows a ring of bubbles. Once that's done, it dives down and then surges up through the middle of the ring, engulfing the bounty corralled by the bubbles in its cavernous mouth. The whale is bubble-net feeding for krill, its primary food source in Antarctica.

Dr Ari Friedlaender, professor of ocean sciences at the University of California, Santa Cruz, is also aboard the boat and has seen this behaviour many times before. Nevertheless, the perspective provided by the drone offers exciting new insights. "I knew it was making bubble-nets but what I couldn't tell without the help of the drone was how small and tight that net was," he tells me later. "That bubble net was smaller than the whale was long purely because it could pivot around its flipper and you can see that in the video quite clearly."

HERE FOR THE FOOD

Whales – including humpbacks, blue, fin, sei and Antarctic minke – migrate south for the Antarctic spring and summer to take advantage of the fecundity of krill that lives there, the largest biomass of any marine species on the planet. They come because the waters of the tropics, where they mate and give birth, are too warm to produce the vast amounts of →

ABOVE Scientists in a small inflatable boat floating in the vast, freezing expanse of the Antarctic, hope to spot a whale to tag, film and study

→ krill the whales need (the crustaceans not only prefer colder waters but also rely on the algae that grows beneath the ice sheets for food).

When Friedlaender first came to Antarctica in 1998, his task was to count whales. "I saw five or six," he says. "The average air temperature was -30˚C but somehow it didn't put me off. I thought it was the greatest place on Earth."

He has since written the textbook on how to study whales in the Antarctic and what they do there. It's an obvious but often forgotten fact that whales are hard to research because they live in water, so Friedlaender has learned to exploit a range of new technologies to gain insights into their lives. Aside from the drones provided by the WWF, the gadgets at his disposal include suction-cup tags that record everything from a whale's movements over a 24-hour period to video footage that shows what it's like to be one. He also has a means of extracting skin and blubber samples to assess a whale's stress levels and determine whether it's pregnant.

Research of this nature is costly but the most expensive part is getting the scientists and all their equipment to Antarctica (it's a two-day journey by ship from Ushuaia, at the southern tip of Argentina). But here Friedlaender and his colleagues have a helping hand – instead of having to fund their own travel for the 2022-23 research season, they're the guests of an Australian adventure tour company called Intrepid.

Intrepid provides berths and food aboard its ship, the *Ocean Endeavour*, plus the use of a small inflatable boat. In return, the scientists give updates each evening about their research and why it's necessary. Given the reaction at the nightly meetings, it's a popular addition to the standard talks about penguins and polar explorers. Friedlaender, for his part, welcomes the opportunity to talk to an engaged audience.

"We have metrics for how many people cite our publications and that's important. But the real impact of the science comes from how many people get the message and change their behaviour and attitudes because of it," he says.

It's not a new arrangement, and other Antarctica cruise companies, such as Hurtigruten and Waterproof Expeditions, also offer places to whale scientists but Intrepid is the only one that has the backing of the global conservation group WWF.

ABOVE The devices used to track, tag and film the whales are displayed and explained to people travelling aboard the *Ocean Endeavour* cruise ship

"WHAT WE'RE INTERESTED IN IS THE TREND: ARE WHALES GETTING BIGGER OR SMALLER?"

TOP A humpback whale's fluke can reach widths of up to 5.5m

ABOVE The folds in the flesh on the underside of a humpback whale's mouth, called ventral pleats, allow it to expand to draw in huge quantities of water and krill

TREND SPOTTING

As the team's drone pilot, Chris Johnson's main role is to get simple measurements of the whales' lengths and widths. Groundbreaking research published in 2020 showed that North Atlantic right whales are much skinnier than their southern right whale cousins. Indeed, the northern species suffers from a deadly cocktail of human impacts that may be driving it to extinction. While no one thinks the same thing is happening to whales in Antarctica, the idea is to better understand how they're faring in the medium-to-long term.

"What we're really interested in is the trend: are whales getting bigger or smaller? And something we'll look at is how do we take all this information to determine these trends and make it publicly available," Johnson says.

Whales in the Antarctic feed almost exclusively on Antarctic krill (*Euphausia superba*), a species of shrimp-like crustacean that, while only 6cm long, lives in astonishingly dense swarms of between 10,000-30,000 animals per m^3. Krill's biomass was once considered to be so great that it was inexhaustible but today the idea of it as an infinite resource is being questioned.

That's for two main reasons. The first is climate change. Krill depend on sea ice, underneath which grows the algae that they feed on. The Antarctic is warming faster than any part of the planet and, as sea ice disappears, it'll restrict the range of the species that's the building block of the Antarctic food chain.

The second reason is that krill is gaining a reputation as a health food supplement, marketed by retailers as being rich in omega-3 fatty acids that are good for your heart, brain and vision. It's fed to farmed salmon, pumped into pet food and is even being investigated as a 'super-food' for the US military.

Conservationists accept that krill is not overexploited. There are some 380 million tonnes of it in the Southern Ocean and the total amount caught by fisheries amounts to just 450,000 tonnes, about 0.1 per cent of what's theoretically available. →

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"THE WWF IS USING THIS DATA TO PRESS FOR A NEW MARINE PROTECTED AREA THAT COVERS THE ANTARCTIC PENINSULA"

Not all of the Antarctic's wildlife spends its entire time under water

→ The problem isn't how much the Southern Ocean super trawlers are catching – not yet, anyway – but where they're catching it. "If you look at how the commercial krill fishery works, it overlaps in space and time with the whales [at certain times of year]," says Friedlaender. "You literally have two predators competing for the same resource."

That this is known is largely thanks to Friedlander's high-tech, suction-cup tags. Travelling in boats, he and his team patrol the Gerlache Strait on the west coast of the Antarctic Peninsula, looking for humpbacks and minkes.

When a whale is sighted, the pilot steers the boat so that it'll be behind the animal when it surfaces to breathe. As the whale slowly rises, one of the scientists on board extends a long, lance-like pole with a suction-cup tag on the end. The aim is to be within range (about 5m away) when the whale breaks through the surface of the water, at which point the scientist thrusts the lance forward to stick the tag on to the creature's back.

If they're successful, the tag will spend the next 24-48 hours on the whale collecting data about its movements and behaviour, before detaching and transmitting a signal that the scientists can use to find it. Then the real science can begin.

"All baleen whales have a very strong kinematic signature," Friedlaender explains. "There's a lot of motion that goes into feeding. Their mouths are these massive things that fill with water and when they feed, they accelerate very quickly, open their mouths and then decelerate very quickly as the water fills that volume."

Accelerometers on the tag record this motion and an on-board processor aggregates the absolute values to create what Friedlaender calls a "jerk signal". Video that is recorded at the same time shows the mouth opening and closing, demonstrating that this signal can be absolutely correlated with feeding. Friedlaender has even teamed up with a video games editor to produce a 3D CGI animation of this movement.

This data has revealed that humpbacks will perform up to 800 feeding lunges at the beginning of the Antarctic summer when they first arrive and are, naturally, extremely hungry. Thanks to a GPS capability, the tags also give precise locations for the whales, so Friedlaender and colleagues are beginning to understand where they're feeding, when they're feeding and how much they're eating.

Now, after collecting more than a decade's worth of data, the scientists know that the Gerlache and Bransfield Straits, and adjacent bays such as Neko Harbour, are the most important areas for baleen whales on the peninsula and some of the most important in Antarctica.

WWF is using this data to press for a new Marine Protected Area (MPA) that covers the Antarctic Peninsula. In 2002, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), which regulates all fishing activity in the Southern Ocean, committed to establish a network of MPAs around Antarctica but progress on one for the peninsula, and two others, has stalled.

"There are 26 nations, including the European Union, that are members of CCAMLR, and 24 of them are on board with these proposals. Now it's a question of getting the other two over the line," Johnson says. "China and Russia – that's the real challenge." Despite the obvious obstacles that stand in the

way of making any agreements with these two countries right now, Johnson remains optimistic that it'll happen eventually, saying it all comes down to timing.

CROSSBOWS AND SUSHI

During my time with them, Friedlaender and Johnson are joined by a third team member and, in contrast to their high-tech drones and tags, she has come equipped with a crossbow – an invention that dates back 2,500 years. It's not just any crossbow, though; this one fires modified bolts tipped with metal tubes that extract tissue samples, similar to how a spud gun extracts bullets from a potato.

Standing in the bow of the boat, Natalia Botero-Acosta waits as the pilot approaches a humpback from the rear. It's many decades since whales were last hunted in Antarctica; nevertheless, it's hard to ignore the irony of a scientist poised like a harpoonist, even if it is in the name of saving whales, not killing them.

Just as they draw within 10m of the whale, Botero-Acosta fires. She misses but reloads and fires again, hitting the whale on its flank. The bolt bounces back harmlessly, plopping into the cold seawater where it floats on the surface, waiting to be retrieved.

Back on *Ocean Endeavour*, Botero-Acosta pokes the small sample of skin and blubber collected in the bolt. It resembles a micro-portion of sushi, just a few millimetres in diameter and 2-3cm long. The sample will be frozen, sent to a lab and tested for progesterone and testosterone to assess whether the whale it came from is a pregnant female or, if it's a male, whether it's of breeding age or not. Tests for cortisol will establish the whale's stress levels. If these are high, could it be because of the presence of fishing boats – or even tourist ships. Recorded stress levels were lower during the COVID-19 pandemic when no trips ran.

"We're especially looking for biopsies from females with calves," Botero-Acosta tells me. Recent research, published by Logan Pallin, one of Friedlander's postdoc researchers, showed that the rate of females becoming pregnant immediately after giving birth was surprisingly high, averaging more than 50 per cent over an eight-year period. "That's really interesting because that happens when a population is recovering and has enough food to do so," says Botero-Acosta. "You need a lot of energy to do that, because [for much of the year] that female is either migrating or in the tropics, where she's nursing a calf and not eating."

But Pallin's paper also showed high variability and that years of low pregnancy rates could be correlated with years when there had been a low abundance of krill. In other words, if there wasn't enough food, females were not in sufficiently good condition to get pregnant. It's another piece in the jigsaw of how Antarctica's whales are faring and what may affect them in the future.

There's a good reason why we should all be concerned about maintaining and even restoring whale populations. Each great whale amasses nearly 30 tonnes of carbon dioxide during its lifetime (a tree, in comparison, sequesters just over 20kg a year) and when it dies, that carbon is usually deposited on the seabed. Not only that, but whales' waste products provide essential ingredients for the growth of phytoplankton, tiny marine algae that absorb four times as much carbon as the entire Amazon forest each year. In short, the more whales there are, the more carbon is taken out of the atmosphere.

Back in Melbourne, after the expedition, Chris Johnson is mulling over WWF-Australia's next move. A special meeting of CCAMLR is taking place in Santiago, Chile, in July, in the hope that progress can be made on designating the three Antarctic MPAs promised more than two decades ago. He, Friedlaender and Botero-Acosta are doing their bit by collecting valuable data on the whales that rely on the krill in those regions. Now it's up to politicians and policy-makers to do theirs. SF

by JAMES FAIR
(@jamesfairwild)
James is a freelance nature journalist. He spent 18 years as a writer and commissioning editor at BBC Wildlife magazine. *For this story he travelled on Intrepid's WWF Giants of Antarctica trip.*

BELOW Chris Johnson of WWF–Australia is the science team's drone pilot during Antarctic expeditions

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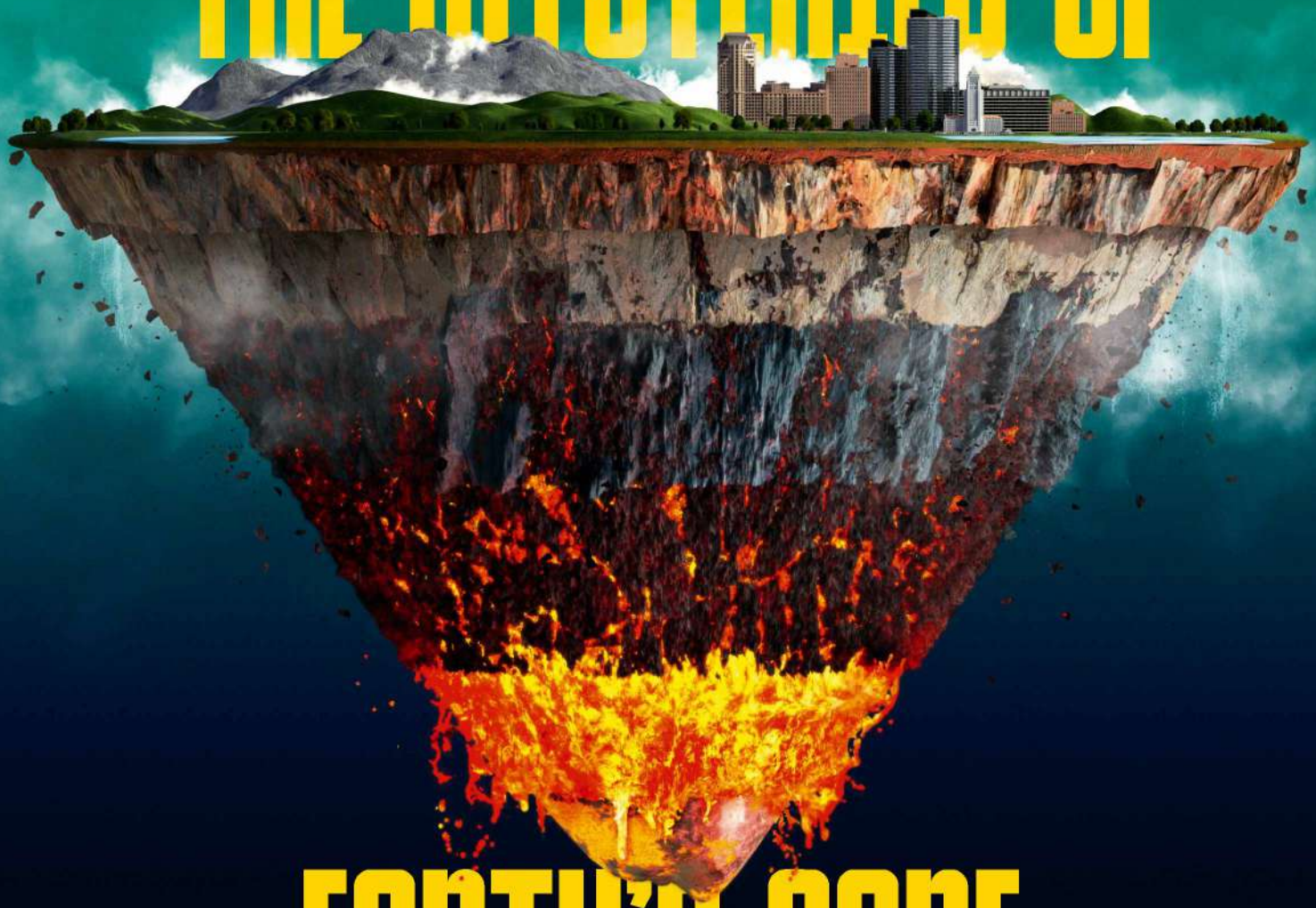
THE MYSTERIES OF EARTH'S CORE



by COLIN STUART

Take even a quick peak beneath Earth's surface and you soon discover just how much we don't know about what's happening right under out feet

WHAT'S IT REALLY MADE OF?

A set of strange signals are telling us a whole new story about what's happening at the core of our planet. And if we can decipher them, we might understand more about Mars's history

We spend so much of our time focused on the world around us that we rarely give much thought to what's going on beneath our feet. If Earth were an apple, the crust that we live on would only be as thick as the apple's skin.

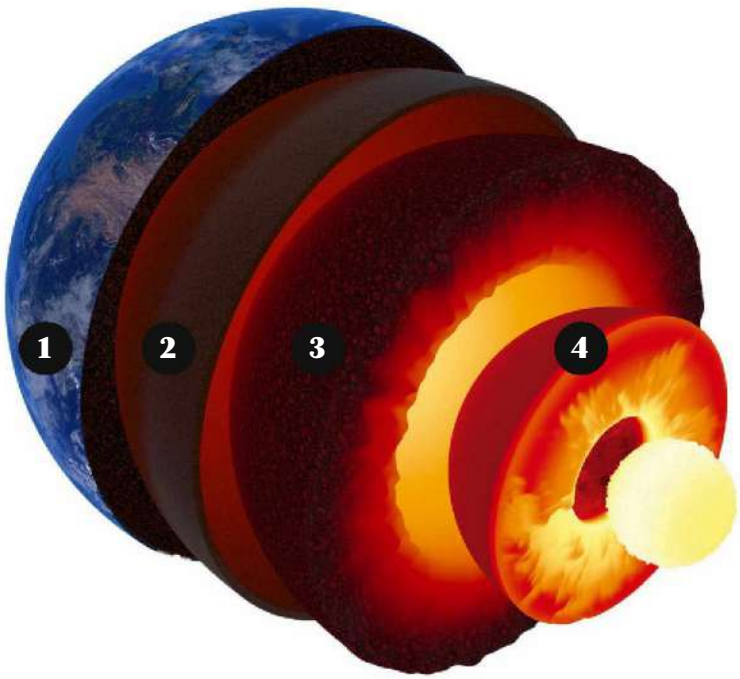
Like an apple, Earth also has a core tucked away within, buried beneath a layer called the mantle. The core formed early, just 200 million years after Earth itself coalesced, some 4.5 billion years ago. Earth's core is large – almost equivalent to half the size of Mars – and there's such extreme pressure crushing down on it that its temperature is as hot as the surface of the Sun.

Earthquakes have played an indispensable role in our understanding of this internal structure. The modern seismometer, invented in 1880, measures the vibrations from earthquakes as they ripple through the planet. In the early 20th Century, scientists assumed that Earth's core was completely molten and the material's movement was responsible for generating the planet's magnetic field. Then, in 1936, the Danish seismologist Inge Lehmann was able to determine, through the use of seismometers, that seismic waves were bouncing off something deep inside Earth. She correctly concluded that the planet's core was composed of two parts: a solid inner core, nested, Russian-doll-style, inside a molten outer core.

But more recent work is revealing that the reality could be a touch more complicated. Dr Thanh-Son Phạm and Prof Hrvoje Tkalčić from The Australian National University tried something different. "We claim the detection for the first time of ricocheting seismic waves, which propagate from →

> "EARTHQUAKES HAVE PLAYED AN INDISPENSABLE ROLE IN OUR UNDERSTANDING OF EARTH'S INTERNAL STRUCTURE"

DOWN TO THE CORE



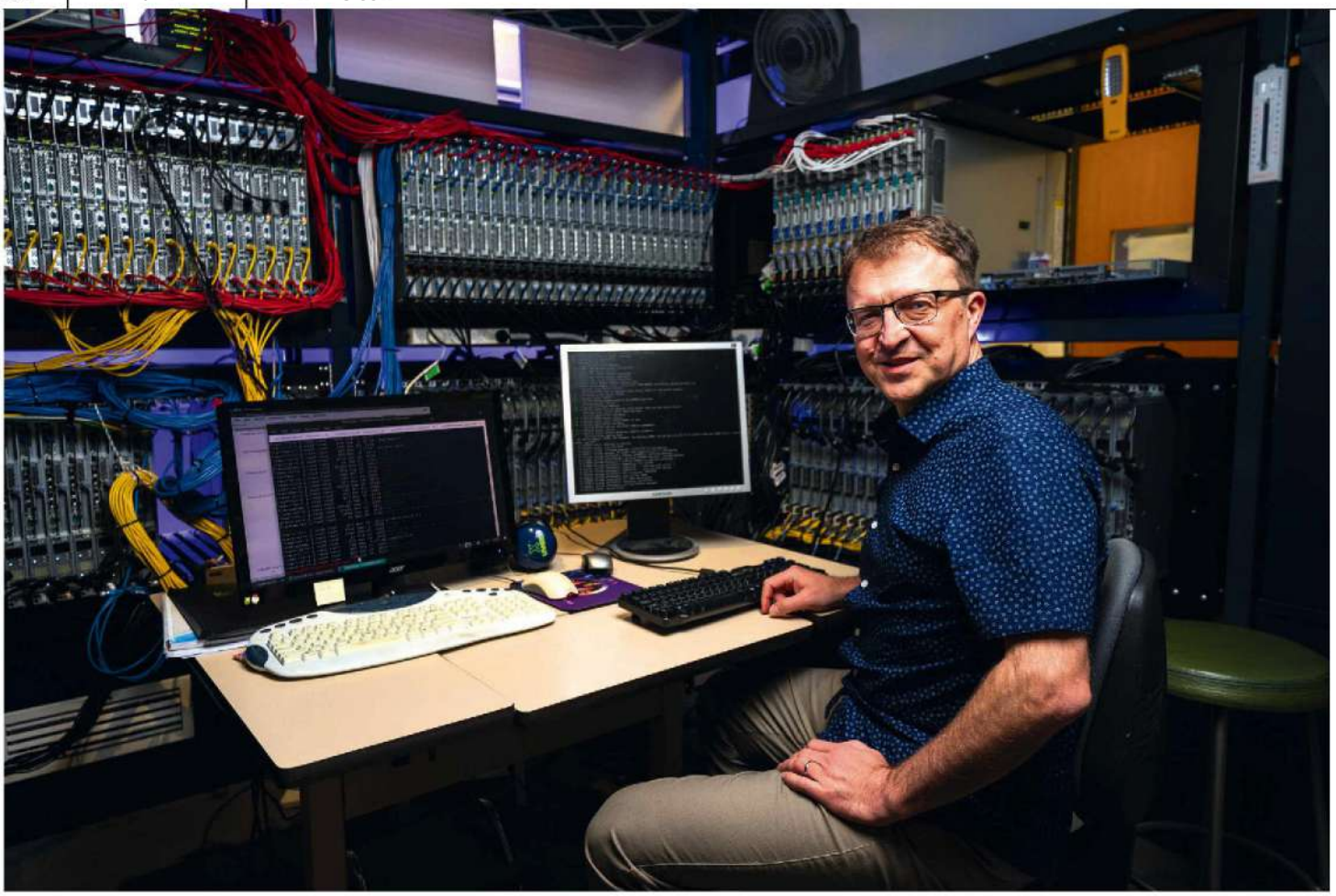
GETTY IMAGES ILLUSTRATION: MAGIC TORCH

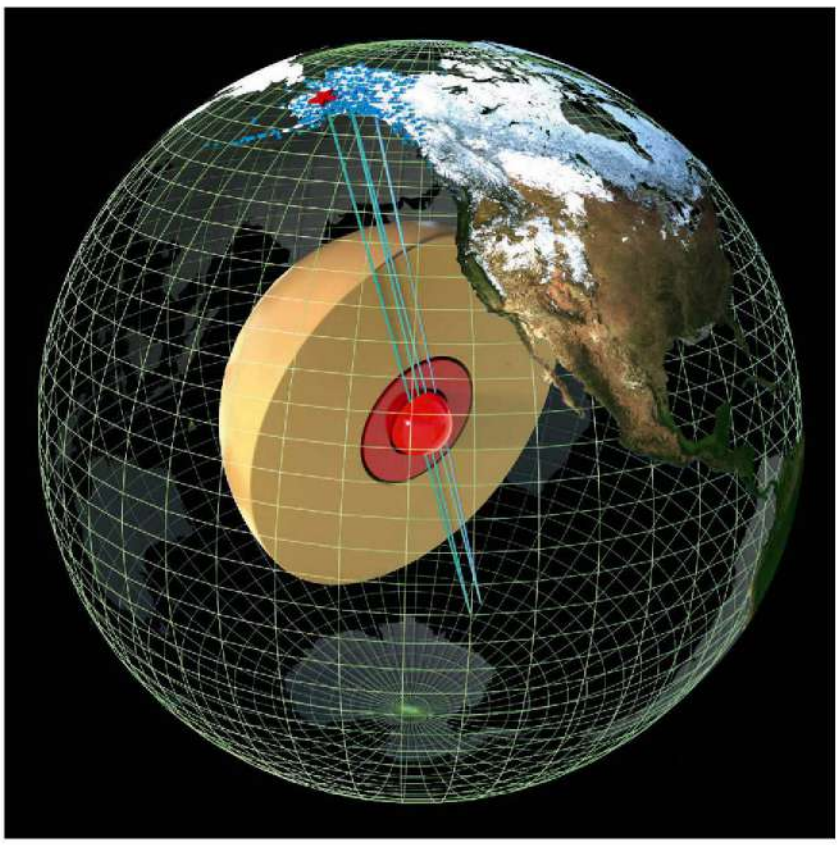
1. Crust
The crust is split into the oceanic crust, which is a maximum of 10km thick, and the continental crust, which can be as much as 80km thick in places. The crust rises and falls by up to 25cm each day as the Moon pulls on it.

2. Mantle
Together, the crust and the top half of the mantle make up the lithosphere, which is broken into tectonic plates that shift. These shifts cause earthquakes and the continents to drift. The mantle is by far the largest part of the Earth, making up 84 per cent of its total volume.

3 Outer Core
This is the only truly liquid layer of Earth's internal structure. Around 2,000km thick, the outer core is mostly iron and nickel, with between five and ten per cent made up of lighter elements. The transition between the inner core and outer core is located approximately 5,150km beneath Earth's surface.

4. Inner Core
A solid, crystallised iron structure that's under immense heat and pressure. Each layer of the crystal structure is thought to be hexagonal in shape, although there may actually be two separate crystalline structures present. The crystals are believed to align roughly north-south to match the orientation of the Earth's rotation axis and its magnetic field.



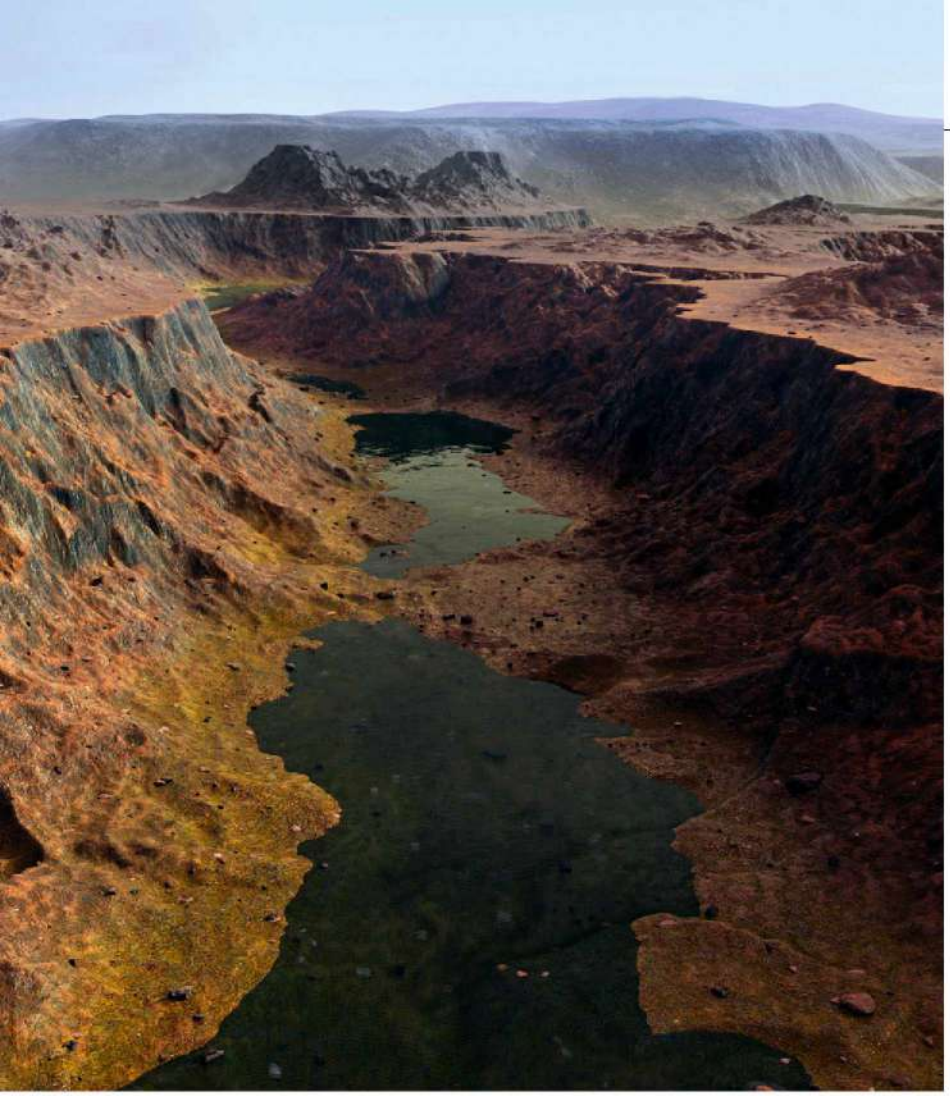


→ the earthquake source to the other side of Earth, and back, up to five times," Phạm says. "The detection is significant because it allows a new way to probe the very centre of Earth, which was very unlikely in the past." It's a technique that's often been used in the search for new minerals but not for probing Earth's inner structure.

Publishing their findings in February 2023, Phạm and Tkalčić analysed data from the growing network of seismometers setup across the planet. The important part was getting data from close to the epicentre of the earthquakes and then from the exact opposite spots on the other side of the planet, known as the antipode. The reason this has been tricky in the past is because earthquakes tend to cluster around an equatorial belt that's dominated by oceans and other remote areas.

When an earthquake strikes the ensuing vibrations reverberate around inside the planet for days. They take about 20 minutes to cross from one side of Earth to the antipode. Phạm and Tkalčić saw up to five back-and-forth bounces from several magnitude-six earthquakes. The waves got weaker with each bounce, so they used a technique called stacking to combine them. This helped the two scientists to draw out more information from the weaker signals. Only two bounces had been analysed prior to their work.

JAMIE KIDSTON/ANU, GETTY IMAGES, FIELD MUSEUM, DREW WHITEHOUSE/SON PHAM/HRVOJE TKALCIC



LEFT An illustration showing how an earthquake that occurs in Alaska can send seismic waves down into the planet that are capable of passing through its core

ABOVE LEFT Prof Hrvoje Tkalčić has been able to probe Earth's core by closely monitoring how seismic waves ricochet back and fourth within the planet's structure

ABOVE An illustration of how the surface of Mars might have looked in the ancient past, when its atmosphere was thicker and warmer

They found that the seismic waves travelled differently through the innermost inner core than the outermost. The waves slowed down when they hit the solid core but they slowed down in different directions. Phạm says that this suggests the crystals of iron that make up the core are arranged differently in the inner core. They estimate that the innermost inner core is 650km thick and takes up slightly more than half of the inner core.

There's more work to be done, however. "The [question of the] nature of the transitional layer between the innermost region and the upper layer of the inner core remains to be answered," Phạm says. "Hopefully, this question can be addressed in the near future."

Understanding its exact structure is important because Earth hasn't always had a solid core – it's believed to have formed between 600 million and 1.5 billion years ago. Insights into its structure could also help astronomers and planetary scientists to understand more about what happened to Mars. Data from Mars rovers hint at a warmer, wetter past for the Red Planet that would have made it a lot more like Earth. If Mars's core solidified completely, its magnetic field would have switched off, leaving it unprotected from the ravages of the solar wind that gradually pecked away the majority of the Martian atmosphere.

WHAT'S HAPPENING TO ITS SPIN?

Our planet's spin is slowing down and our days are getting longer as a result

How long is a day? 24 hours? 86,400 seconds? The answer is no two days are ever the same. A day is defined by how long it takes Earth to complete one rotation on its axis and many factors affect the speed of our spin. The gravitational influence of the Moon has dragged on the day, lengthening it from just under 19 hours 1.4 billion years ago to the more familiar 24 hours today.

This is not only predicted by the physics of tidal forces but also backed up by studies of 430-million-year-old fossilised coral. As the coral grew, it laid down a new line of calcium each day. These lines are arranged in patterns that represent the seasons. There are 420 lines within those patterns, meaning 420 days annually. As the year is the fixed amount of time it takes Earth to orbit the Sun, more days means fewer hours in each one and just under 21 hours at the point the coral stopped growing.

The melting of the polar caps at the end of Earth's regular ice ages has also played a halting role. These are long-term trends. More short-term effects include an earthquake in Chile in 2010 that sped up the planet and shortened the day by 1.26 microseconds. →

Counting the ridges in fossilised coral can be used to determine the number of days there were in a year when it was growing

"SINCE 2020, THE AVERAGE DAY HAS BEEN GETTING LONGER – EARTH IS SLOWING DOWN"

BELOW Prof Xiaodong Song has reason to believe Earth's inner core may be slowing down, after studying how seismic waves travel through the planet

→ In fact, 29 June 2022 was the shortest day ever directly recorded.

But something strange appears to be occurring in the short-term trends. Since 2020, the average day has been getting longer – in other words, Earth is slowing down. This goes against a previous pattern of the average day shortening for the half-century before that.

So what's going on? Prof Xiaodong Song and Yi Yang from Peking University in China believe they may have the answer and they think it's Earth's inner core.

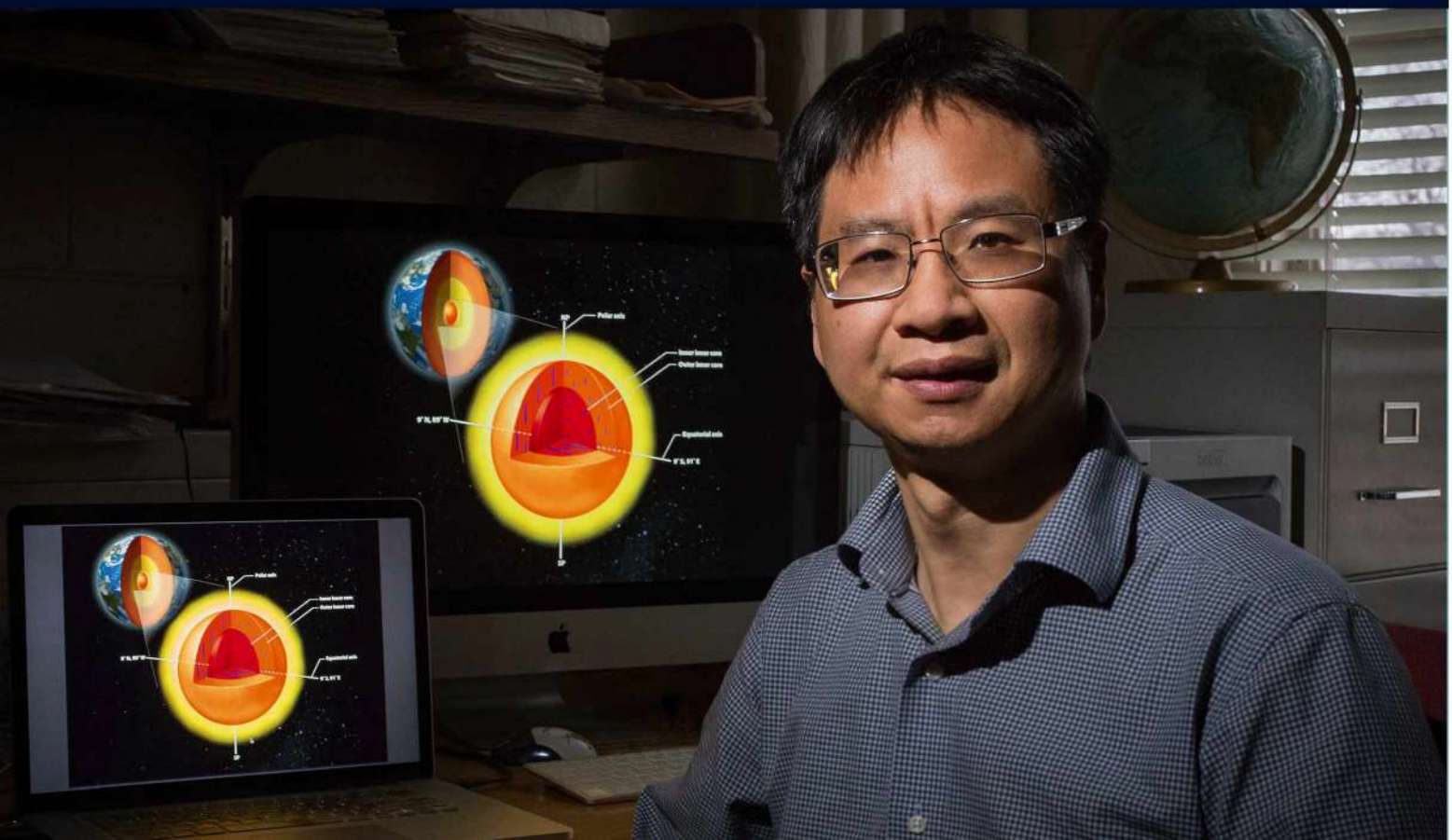
The solid inner core sits inside the cocoon of the liquid outer core and so it's not rigidly held in place. It's free to spin at a different rate to the mantle and crust above. The inner core used to spin faster than the rest of the planet but Yang and Song suggest that it has slowed down recently and may even be rotating slower than the layers above.

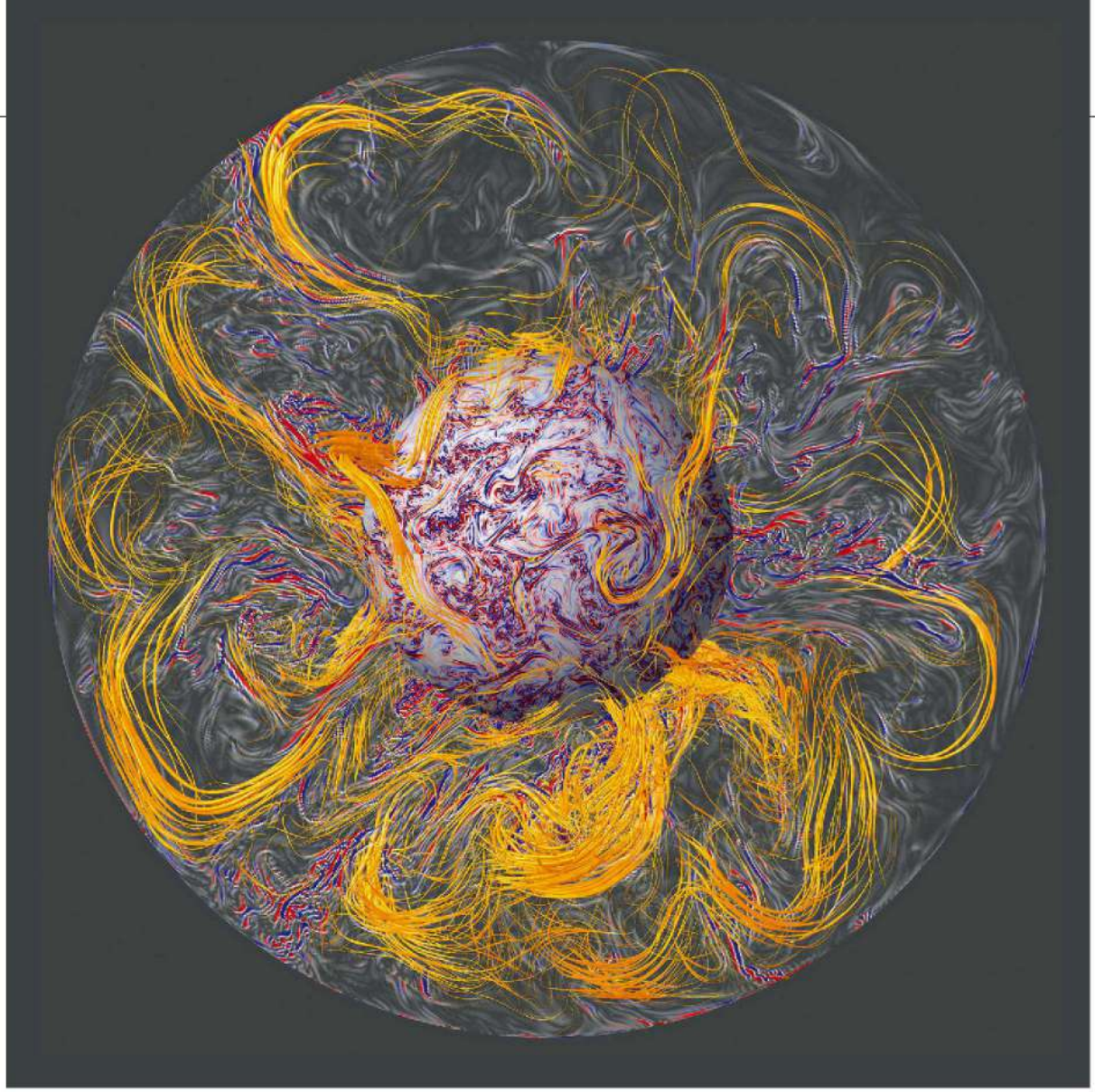
The pair looked for seismic events that happened in the same location many years apart. In particular they studied earthquakes erupting close to the South Sandwich Islands in the Atlantic and the resulting seismic detections in Alaska. Their paper also mentions seismic waves recorded in Montana, US, from two nuclear tests conducted at Novaya Zemlya, USSR, in 1971 and 1974.

If the core hasn't changed, then it should reflect the seismic waves in the same way and they would look almost identical at the surface. Except that's not what Song and Yang found. The differences they saw led them to conclude that, since 2009, the inner core has been slowing. By comparing this data to older measurements stretching back to 1964, they conclude that this behaviour is "part of an approximately seven-decade oscillation, with another turning point in the early 1970s." Perhaps the core speeds up and slows down in a repeating pattern.

It's a tentative finding, one that needs more supporting data, and other researchers have put forward alternative explanations. It could be that the surface of the inner core isn't as smooth as generally believed, for example. If it's rougher then that could change how the inner core reflects seismic waves without needing a change in speed.

If the core does turn out to be slowing down, what could be behind it? Well, the inner core isn't completely free to move – it's partially pinned by the gravity of the mantle. Some geophysicists argue that this sets up a cycle in which the inner core slows down and speeds up. Perhaps we're just observing a short part of this cycle and it'll speed up again very soon. With an unprecedented number of seismometers scattered across the planet – and more being added all the time – we may not have to wait too long for answers.





JULIEN AUBERT/IPGP/CNRS, UNIVERSITY OF ILLINOIS/L BRIAN STAUFFER

LEFT A simulation showing how magnetic field lines (orange) in Earth's core are manipulated by convection currents. The turbulence this creates spreads up, out of the core, giving rise to geomagnetic jerks

WHAT'S GOING ON WITH OUR MAGNETIC FIELD?

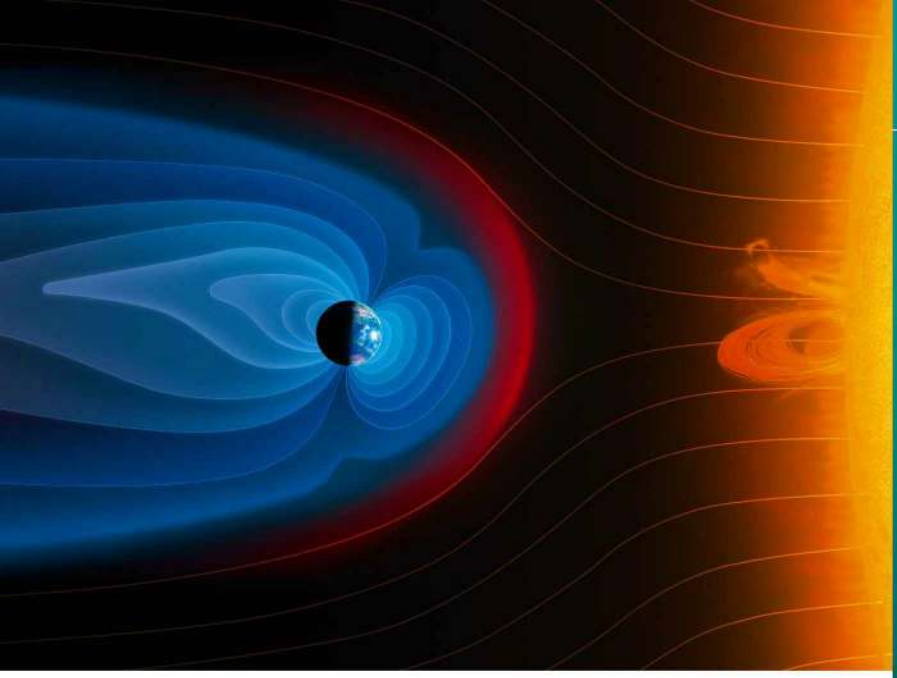
Earth's magnetosphere keeps us safe from the radiation pouring out of the Sun. But recent research suggests the whole thing could be about to turn upside down

Earth's magnetic field is a behemoth. It stretches some 65,000km towards the Sun but on the night side of the planet extends beyond six million kilometres. That means that for about a week of its month-long journey around Earth, the Moon is embedded within our magnetic field.

The core is behind all this. As heat escapes from the solid inner core it surges into the molten outer core and drives convection currents. Electrically charged material is moved around, which generates a magnetic field that flows up through the crust and out into space where it meets the solar wind – the high-energy stream of particles from the Sun. It's this interaction that pushes our magnetosphere so far out on the night side of Earth.

The magnetosphere has kept life on Earth safe for billions of years. For centuries, explorers relied on compasses aligned with it for navigation and animals follow it to find their way, too. And yet, it's not as constant as it may seem.

In the 1970s scientists spotted a phenomenon called geomagnetic jerks – abrupt and unpredictable changes in our magnetic field. But they only began to understand them once we started looking down at ourselves from space. Then, in 2019, Julien Aubert of the University of Paris and Prof Christopher Finlay of the Technical University of Denmark released the results of a supercomputer simulation of the outer core. They found that waves created in the inner core spread into the outer core and →



→ cause sharp changes in the flow of liquid beneath the magnetic field. It can take 25 years for a rising blob of metal to lead to a geomagnetic jerk.

Our magnetic field can also flip. When lava cools it preserves information about the direction of the Earth's magnetic field at the time. By analysing layers of lava, researchers have shown that, on average, the direction of our magnetic field reverses every 200,000 years. The last flip was 780,000 years ago and there are signs another one may be on the way.

According to the European Space Agency, over the last 200 years the global average strength of our magnetic field has dropped by nine per cent. Such drops have preceded previous reversals. In some spots the reduction has unfolded at any even more dramatic pace. Take the so-called South Atlantic Anomaly (SAA), which sits over South America. "It's a region where geomagnetic intensity is the lowest," according to NASA geophysicists Weijia Kuang and Terence Sabaka. But it's also changing.

"Observations have found that the SAA is expanding and moving westward," Kuang and Sabaka say. The field strength of the SAA also dropped by eight per cent between 1970 and 2020. What's causing it? "The short answer is that the SAA is due to vigorous convection in Earth's outer core," say Kuang and Sabaka. It's associated with a magnetic reversal in the outer core that works against the main magnetic field.

This has some downsides. Several satellites moving through the region have failed due to the intense radiation that leaks in from space. Astronauts can't perform spacewalks if they're in the vicinity. The former astronaut Terry Virts even said he saw a massive flash of light, while his eyes were closed, when passing over it.

But the SAA does help geophysicists to understand what's going on in the bowels of the planet. According to Kuang and Sabaka the SAA can be used to map the flow of material in the topmost part of the outer core. "The SAA forecast accuracy can [also] be used to estimate the entire core state, which is not observable from Earth's surface or in space," they add.

ABOVE Earth's magnetic field protects us from the high-energy solar winds that burst forth from the Sun

WHAT'S ITS FUTURE?

Will it stop spinning? Will it solidify completely? And what will it mean for those of us living above it?

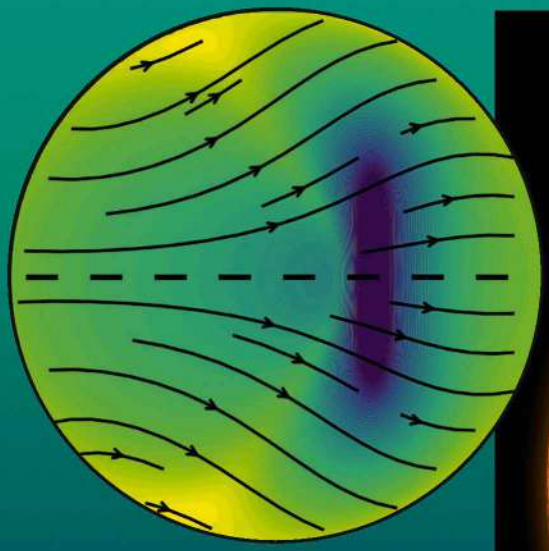
Earth's core can trace its history back to the formation of the planet. When the Sun sparked out of a cloud of interstellar gas and dust, a band of leftover material formed around it. This protoplanetary disc was laced with the iron ejected into the Universe by the cataclysmic supernovae that mark the end of the lives of the most massive stars.

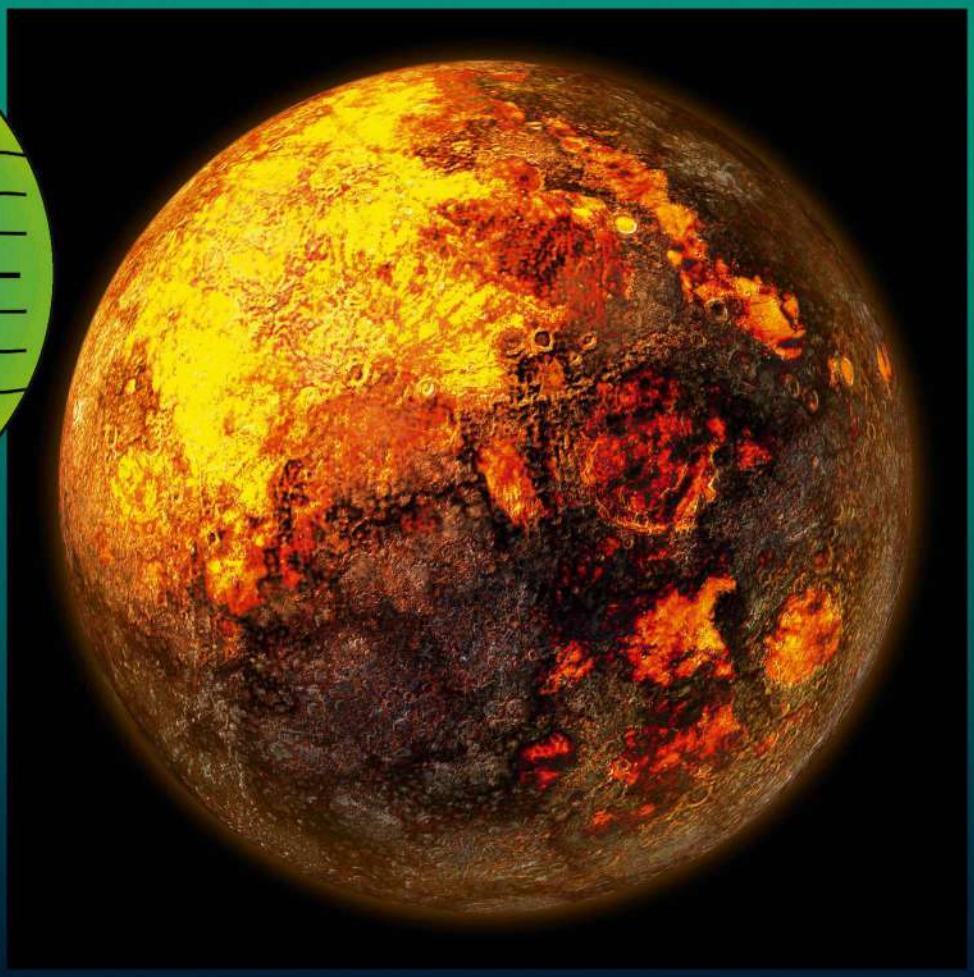
Gradually, gravity fashioned this material into lumps of rock and metal called planetesimals and they smashed together to form planets. The impacts were so forceful that the rock and metal melted and gravity could round out the new object into a sphere. The heavy iron sank to the middle and the lighter rock floated to the top. As the planet cooled, a crust formed on the surface but the iron core remained molten. This was sustained by the immense gravitational pressure of the layers above crushing down on the core.

But all this happened billions of years ago and the core has been cooling ever since. "As the liquid iron in the outer core cools it slowly freezes into solid iron and becomes the inner core," says Dr Dan Frost, a seismologist at the University of South Carolina.

This process adds 8,000 tonnes of iron to the inner core every second – the equivalent of the mass of the entire human population added daily. As the inner core cools, energy is transferred to the outer core, which drives convection and creates our global magnetic field.

Yet new research led by Frost is hinting that the growth of the inner core is uneven. The eastern part of the inner core lies beneath Asia and the Western Pacific, while the western part sits below the Americas and the Atlantic. Frost's team set about measuring the growth across these far-flung parts of the planet's interior. It's a tricky thing to do when all you've got to go on are measurements made from the surface. "We can't measure that the inner core is a little bit bigger today than it was yesterday, our measurements aren't that sensitive,"





"THE PROCESS ADDS 8,000 TONNES OF IRON TO THE INNER CORE EVERY SECOND"

Frost says. "We're looking for evidence of movement within the inner core."

Seismic waves travelling through the inner core move faster when they move parallel to Earth's rotation axis (roughly north-south) than when they travel parallel to the equator. "We think this means that the crystals in the inner core are all aligned in a similar direction," Frost says. "The way to get that alignment is if the inner core moves." It's similar to the way that sticks dropped into a river align with the direction of the flowing water.

Frost's team found that the core below the Banda Sea near Indonesia is growing faster than the side beneath Brazil. The lop-sidedness doesn't last, however. "Gravity forces [the wider part] back into the centre," says Frost. "That flow of material would cause the crystal alignment that we see."

Frost's work does assume that the inner core is only made up of one type of crystallised iron. We've already seen that other work hints at a difference between the outermost inner core and the innermost inner core. Frost isn't convinced of those conclusions. "There isn't a sharp transition between an outermost and innermost inner core," Frost says. "It's more of a smooth transition." Frost says that such a model is compatible with his findings.

It just goes to show that many mysteries surrounding Earth's solid core remain unsolved. We've only known of its existence for less than a century. Perhaps the next century will bring more insights and a deeper understanding of the mechanism that keeps us all safe from the ravages of radiation being blasted at us from space.

Nor should we worry about the core completely solidifying any time soon. Its growth is slow. The inner core is only getting about 2mm wider every year. Although fast for a geological process, some estimates suggest it would take another 91 billion years for the molten outer core to disappear. The dying Sun will fry Earth long before that happens. SF

by COLIN STUART
(@skyponderer)
Colin is an award-winning astronomy writer.

ABOVE Earth in its earliest days as a protoplanet was a seething-hot mass, with molten rock near the surface and heavier liquified iron sinking down to form the planet's core

ABOVE LEFT A new model of Earth's core is uneven and grows faster on its eastern side, beneath Asia. This may explain why seismic waves take different times to travel through the core

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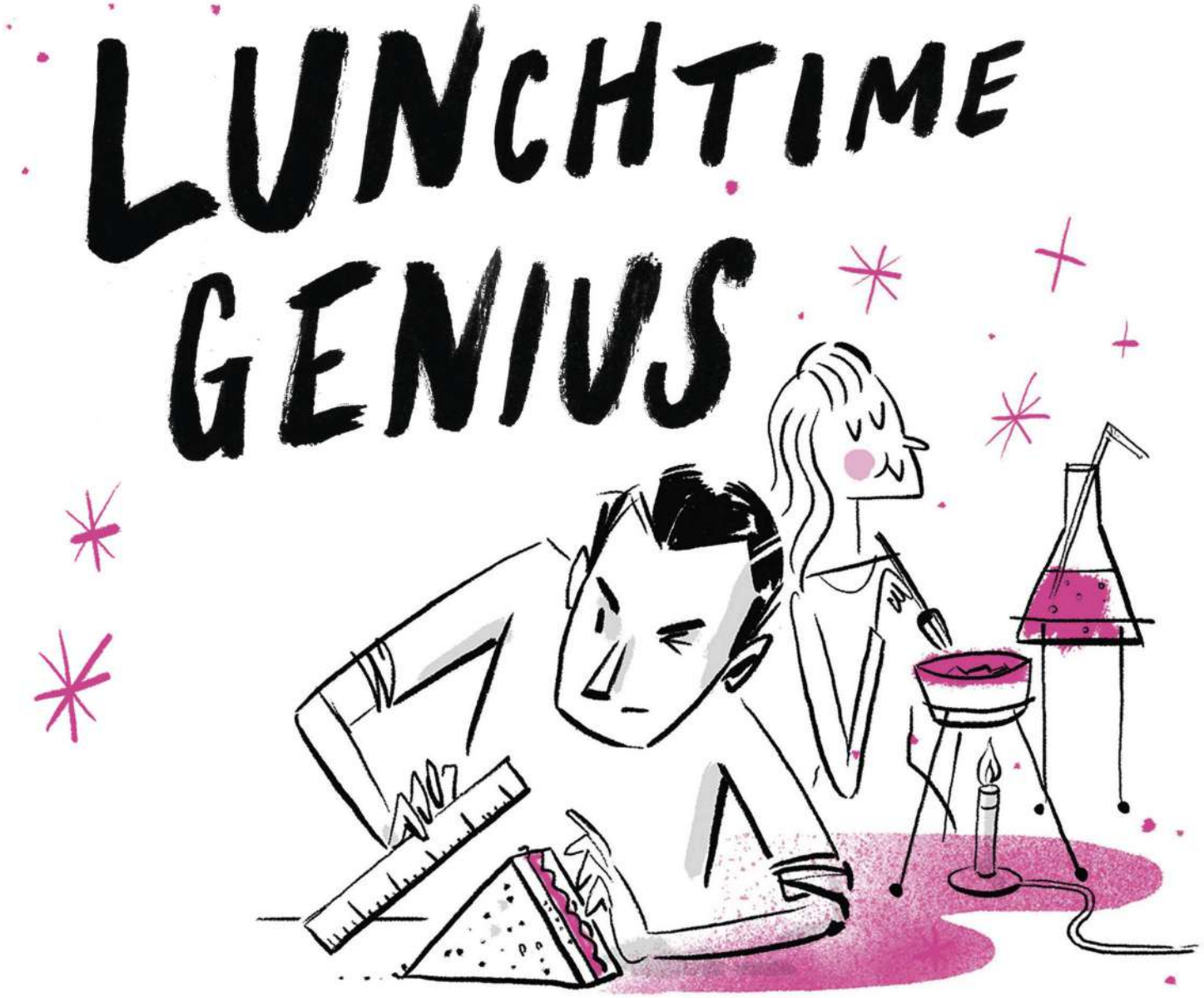

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Q&A

YOUR QUESTIONS ANSWERED

... HOW OFTEN SHOULD I CHANGE MY WASHING-UP SPONGE?
... IS IT POSSIBLE TO INHALE AN INSECT INTO YOUR LUNGS?
... HOW IS HAIL MADE?
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... IF A VIRUS WIPED OUT HUMANS, WHAT SPECIES WOULD TAKE OVER - AND COULD THEY DEVELOP TECHNOLOGY THAT WE WOULD RECOGNISE?

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OUR EXPERTS

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ILLUSTRATION: DANIEL BRIGHT

JOHN HEWITT, VIA EMAIL

WHAT IS THE POWER POSE? AND WILL IT REALLY BOOST MY CONFIDENCE BEFORE A JOB INTERVIEW?

A power pose is essentially any kind of body position that involves taking up more space. Imagine standing with your legs astride and your hands on your hips, or – as used in the seminal research on power poses from 2010 – leaning back in your chair with your legs up and your hands behind your head. The opposite is a contractive pose that involves taking up less room, such as hugging yourself with your legs crossed.

The idea that power posing can give you a jolt of extra confidence was popularised by Harvard psychologist Amy Cuddy's 2012 TED talk: "Your body language shapes who you are," which has been viewed over 68 million times. Cuddy was a co-author on that 2010 research paper which claimed a minute spent in an expansive posture led participants to feel more powerful, take more risks and enjoy a testosterone boost. Amusingly, several Conservative party politicians at their 2015 conference appeared to take the concept to heart, posing on stage with their feet ridiculously far apart (if you fancy a laugh, just Google it).

Since the 2010 paper, research into power posing has descended into a drawn out and bitter dispute between advocates and sceptics, as part of the larger 'replication crisis' in psychology – in which it has proven difficult to replicate some of the field's more eye-catching results. To summarise a complex debate, the evidence seems to be stronger that power posing can help you feel more confident, but largely lacking when it comes to effects on physiology or behaviours, such as taking more risks. Just to complicate matters further, a comprehensive review from 2020 suggested the effects on confidence are actually more likely due to avoiding constrictive postures rather than adopting expansive ones.

My own take is that power posing is a pretty low-risk strategy – at least if you do it in private. So why not try it before that job interview – if it works, great, if not, well you might give yourself a giggle at least. ***CJ***

GLENN FLOYD, GATESHEAD

HOW OFTEN SHOULD I CHANGE MY WASHING-UP SPONGE?

Don't replace it – swap it for a brush. That's one interpretation of a 2022 study, which found more bacteria on the average washing-up sponge than there are people on the planet. The authors claim it's impossible to stop bugs growing on a wet kitchen sponge unless you change it daily, whereas a brush harbours fewer germs because it dries out faster between uses. If you do prefer a sponge – and you're not alone, as people in eight out of ten European countries do – then you might be relieved to know that neither tends to collect the kinds of germs that cause diseases. (Which is enough to convince me that I never need to replace it. But that's our dirty little secret, right?) ***HB***

MEGAN HARRISON, HERTFORDSHIRE

IS IT POSSIBLE TO INHALE AN INSECT INTO YOUR LUNGS?

Your airway has two important defences to prevent this. First, the trachea (airway) is coated with mucus that will tend to trap small insects, with tiny hair cells that constantly sweep trapped particles back up. Secondly, we have a very sensitive reflex that causes a coughing fit when anything touches the walls of the trachea. To suppress this reflex, you would normally need to be drugged or unconscious and it's unlikely you'd be taking deep breaths. Any bug that did make it inside would not survive long, but its tiny corpse could cause an infection leading to aspiration pneumonia which is a serious condition if untreated. ***LV***

NATURE'S WEIRDEST...

SHAMPOO GINGER LILY

Tired of taking two bottles into the shower? Simply snip off the club-shaped flower head of the shampoo ginger lily plant – you can't miss it; it's the one that looks like an embarrassed pinecone – and squeeze the spongy structure onto your scalp. The clear, fragrant liquid that is released, acts as both shampoo and conditioner, bringing a silky vibrancy to your hair that you never knew you were missing.

'So, where do I find this organic, plastic-free marvel?' I hear you ask. 'The tropical parts of Asia and Australasia,' I tell you. 'That's too far,' you say. 'Cool your jets,' I reply, 'you can also grow it as a houseplant.' Shampoo ginger lily, also known as pinecone ginger, is an aromatic, clump-forming, perennial plant, that likes bright light and moist soil. Leaves fall and stems shrivel in the autumn, leaving behind creeping underground stems, known as rhizomes, which give rise to new shoots in the spring.

The plant has other uses too. For example, the aromatic leaves can be used to add flavour to meat dishes, *à la* bay leaf, while the rhizomes can be dried, pulverised, and used as a seasoning or as a perfume. It might just help you to feel good too. Scientists have shown that a bioactive compound, isolated from the rhizome, has antioxidant, anti-inflammatory, and anti-cancer properties. ***HP***

GETTY IMAGES X4 ILLUSTRATIONS: DANIEL BRIGHT

LARA EATON, MANCHESTER

HOW IS HAIL MADE?

Many of us have experienced those hot summer days which start off with sunshine, before towering cumulonimbus clouds bubble up through the day, eventually bringing thunder, lightning and torrential downpours. In some instances, those thunderous clouds can also deliver hail – small balls of ice that fall to the ground. But how does hail form?

When clouds reach the dizzy heights of cumulonimbus status, their peaks can ascend to 10-15km in the sky. By this point, they aren't full of just ice crystals, but also supercooled water droplets; water still in liquid form, despite its temperature being below freezing.

Within cumulonimbus clouds, the air is very turbulent – moving up and down, causing updraughts and downdraughts, which are strong enough to bounce ice crystals around inside the cloud. As these ice crystals move around, they gather extra layers of ice, allowing a hailstone to form and grow.

Not to be tried at home, but if you sliced a hailstone down the middle, it would have concentric rings like a tree, denoting each layer of ice gathered on its journey.

For as long as the updraughts and downdraughts are strong enough to carry the hail, it will remain inside the cloud and continue to get bigger. However, when the hail becomes heavy enough, updraughts can't hold it up anymore, and it falls to the ground.

So how does the ball of ice manage to make it to the surface without melting, when summer air temperatures can be in the range of 25 to 30°C? The answer is the speed at which it falls. Small hailstones typically fall to the ground at a speed of 15-40km/h. This speedy descent means that the ice doesn't have enough time to melt before reaching the surface. ***LD***

DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY OUR EXPERTS

KENDRA PARK, VIA EMAIL

WHY DOES MY SKIN FEEL MORE SENSITIVE TO TOUCH WHEN I HAVE A COLD?

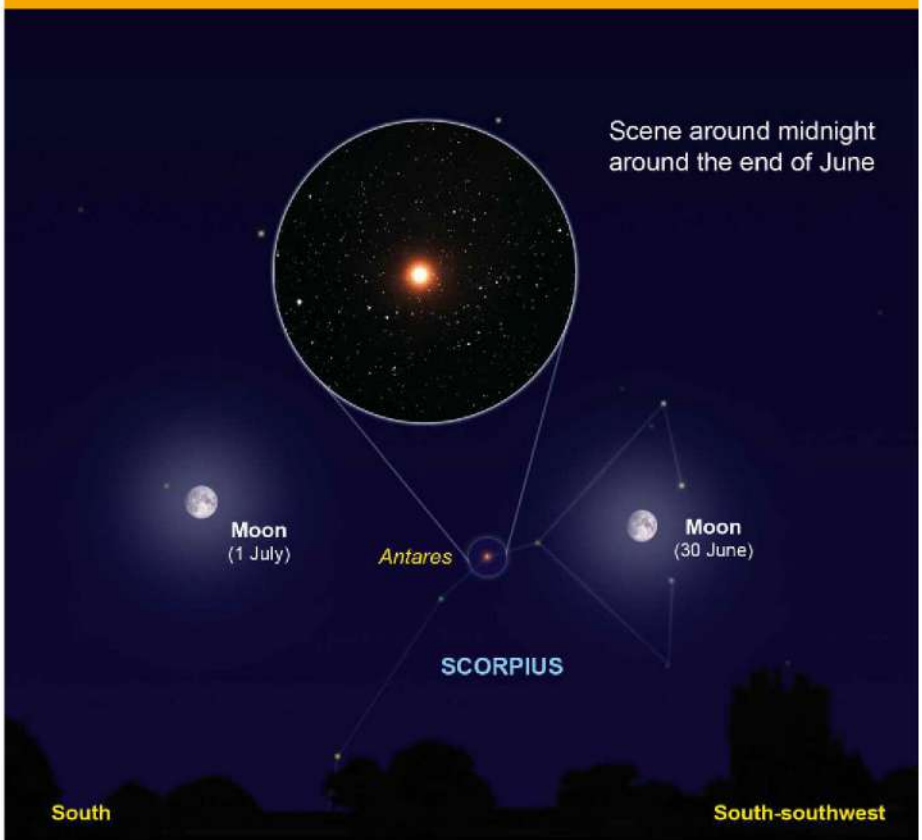
If you've noticed that your skin feels extra sensitive when you're ill, you're not alone – and there are several reasons why this might happen. Sometimes when you're unwell, you have a fever. When your body gets hot, it can make your skin feel uncomfortably warm (similar to how you might feel if you got sunburn). This could potentially make it feel more sensitive. Remember that a fever is a sign your body is fighting the infection, and while it might make you feel miserable, it isn't necessarily harmful.

Another reason for the increased sensitivity could be that your body is also aching from the illness, which makes it feel different to touch. You might also be dehydrated, leaving your skin more irritable and uncomfortable, and possibly more sensitive. Some people have claimed that the trigger to your immune system when you're unwell can lead to heightened sensitivity, but the exact mechanism behind this isn't fully understood.

Usually, this type of skin sensitivity is only temporary, and isn't a cause for concern. Taking simple medication to combat the fever can help, such as paracetamol. Most of the time it needs rest and time and will improve as the illness resolves.

There is a specific type of long-term nerve pain that leads someone to be extremely sensitive to touch, called allodynia. This is a symptom rather than a disease in itself and can have many different causes. The most common causes of allodynia include diabetes, shingles, fibromyalgia, and migraine headaches – not usually just a simple cold. *NM*

ASTRONOMY FOR BEGINNERS



ANTARES: THE RIVAL OF MARS

WHEN: JUNE

If you've never seen Mars in the night sky before, you've just about got time as it's visible low above the west-northwest horizon shortly after sunset. It's currently near to bright Venus, which has also become rather low after the Sun sets. Mars is fading in brightness as the distance between it and Earth increases. Currently it looks like a middle-bright star, its salmon-pink colour being the one characteristic that really makes it stand out.

At this time of year from the UK, there's a bright star visible low above the southern horizon in the early evening as darkness descends. This is the brightest star in the constellation of Scorpius, the Scorpion, and is named Antares. Star names can sometimes give a clue to their meaning. Here the name literally means 'rival of Mars' or 'Ant Ares', Ares being the Greek name for Mars.

It's an appropriate name too, because Antares is a red supergiant star, estimated to be nearly 700 times larger than our own Sun and around 75,000 times more luminous. In the night sky it appears on average (it's an irregular variable) as the 15th brightest star and, like Mars, has a distinctly orange hue. It marks the position of the heart of the scorpion. Scorpius is a constellation that never gets to reveal its true glory from the UK, truncated by our southern horizon when its best placed and due south. As the sky darkens, look out for the two fainter stars that flank Antares and the group of stars further to the west (right), which mark the scorpion's claws.

The almost full Moon lies west (right) of Antares on the night of 30 June into the morning of 1 July, and east (left) of the star on the night of 1 July into the morning of 2 July. ***PL***

ELIZABETH HUMPHREY, BATH

WHAT CAUSES PREGNANCY CRAVINGS?

Cravings are something many mamas-to-be are familiar with. Whether it's ice cream, chocolate, pickles, or something obscure, the body knows what it wants during pregnancy and makes sure we know about it. While pregnancy cravings are not fully understood, there are a few theories about why women might feel these hankerings, one of which is due to changes in hormone levels.

Rising oestrogen and progesterone during pregnancy can increase the sensitivity of taste buds, making certain flavours – like sweet and sour – more appealing. As a result, foods that are normally not enjoyable, may become new favourites. These hormones also increase the production of another hormone, dopamine, which is involved in the body's reward system and promotes feelings of happiness. This means women may experience greater pleasure from certain foods. Progesterone also increases the release of ghrelin, a hormone that causes feelings of hunger and cravings for certain types of foods.

Another theory is that pregnancy cravings may be the body's way of signalling a need for specific nutrients that are necessary for the growing baby. For example, pregnant women need a much greater amount of iron in their diet because it is required to make blood for both them and their baby and to supply the baby with oxygen. Not getting enough could lead to cravings for red meat, such as burgers or other iron-rich foods.

Psychological factors may also play a role in pregnancy cravings. There's no denying that pregnancy is sometimes stressful, and many women experience anxiety around childbirth as well. For those who find food a source of comfort, these feelings can perpetuate cravings.

Not all women experience cravings, but for those who do, they can be hard to ignore. Healthcare professionals can provide nutritional guidance and may suggest dietary changes to help ensure that mother and baby are getting the nutrients they need. ***HM***

DUNCAN DAVIDSON, VIA EMAIL

WHAT IS THE SUPINE POSITION?

The supine position is simpler than it may sound. It describes the position of the body when lying flat on the back, with the face and torso facing up. In this position, the limbs are generally straight, with the palms facing upward. It's commonly used in medical procedures, such as surgical operations, physical examinations, and diagnostic tests, as it allows easy access to the body and provides a clear view of the patient's face and chest.

You'll likely come across it in yoga, Pilates, or other forms of low-impact exercise, as it's a useful way to find neutral spine and neck postures. In some cases, and with the proper support, it can improve sleep quality by allowing a better oxygen flow and relaxing the diaphragm, although other studies found that right-sided sleepers had better sleep quality.

However, it's not a posture with cure-all abilities: for individuals with sleep apnoea, the supine position can exacerbate the condition. Some studies suggest that simple interventions (such as sleeping on the right side) can improve sleep apnoea symptoms.

In yoga, the supine position is the base for the Savasana pose (also called the 'Corpse Pose') which aims to relax the body while maintaining an awareness of the mind and breath. It can also be used to target specific, hard-to-stretch areas of the body.

Supine postures are primarily used as a counter pose to maximise the benefits of more 'dynamic' postures, or to release and stretch thigh muscles in specific areas. "A supine twist is a release for the entire spine, but specifically the lower back, which is often affected by tight hips, glutes, and hamstrings," says yoga instructor Allie Williams.

The case for Pilates is slightly different. The supine position is used during abdominal exercises, which improve muscular endurance and trunk flexibility. A study conducted in 'sedentary adult females' showed the supine position had a positive effect on abdominal and lower back muscular strength, as well as endurance and torso flexibility, in which the 'neutral spine' position plays a key role. ***VHG***

CROWDSCIENCE

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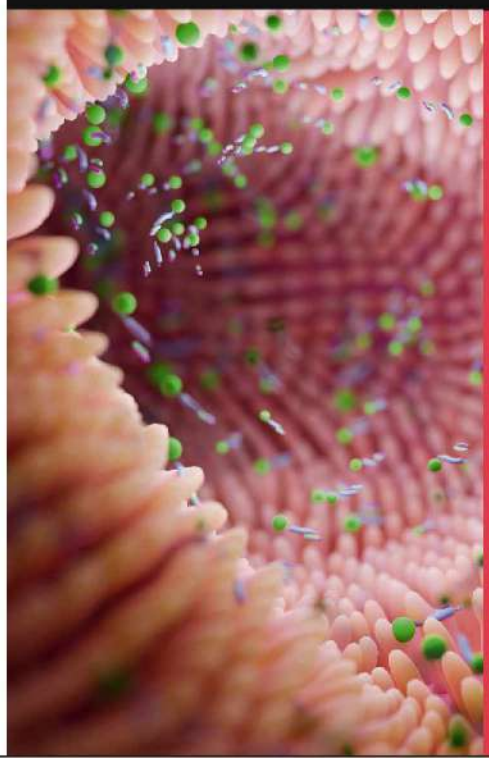


WHAT'S LIVING INSIDE MY GUT?

Rather a lot! The gut is a universe of trillions of microorganisms known as microbiota, and collectively make up the microbiome. This microbiome is now best thought of as a virtual organ of the body. It weighs about 2kg and is bigger than the average human brain. It's made up of trillions of bacteria, archaea, fungi, and viruses, containing at least 150 times more genes than the human genome.

We are teeming with microbes, which form microbiomes on our skin, in our mouths, lungs, eyes and reproductive systems. But the gut's microbiome is the largest, and its composition can vary per person. It also has an important role: it is thought that our microbiota stimulate the immune system, break down potentially toxic foods, and help to produce certain vitamins and amino acids.

Studies suggest that having a diverse population of gut microbes is associated with better health, and poor gut health is associated with a range of conditions, from obesity and brain diseases to depression and inflammatory bowel disease.

There's been a lot of hype around how and what we eat, and how special diets can influence our gut microbes. What we know, is that dietary amounts of protein, saturated and unsaturated fats, carbohydrates, and dietary fibre can influence the abundance of different types of bacteria in the gut. According to research, the richer and more diverse the community of gut microbes are, the lower your risk of disease and allergies. *NM*

GETTY IMAGES X2, ALAMY ILLUSTRATION: PETE LAWRENCE

MYTHBUSTERS

SHOULD I START WASHING MY HAIR WITH BEER?

A quick search online, and you will find lots of articles suggesting that beer used as a shampoo, hair mask, or rinse at home, can result in healthy, shiny locks and even promote hair growth. There are recipe suggestions for adding natural ingredients to flat beer – like honey, apple cider vinegar, or egg (as well as oils like jojoba) – to supposedly enhance its conditioning abilities. And in recent years, several new hair products have come to market containing beer, claiming to leave you with luscious, silky locks.

The alcoholic brew has long been popular among celebrities and stylists, as a part of a holistic hair care routine. In 2009 Hollywood actress Catherine Zeta-Jones revealed that she uses beer and honey to condition her beautiful, black mane, which fuelled enthusiasm for it.

Why would anyone think of putting beer on their hair in the first place? Well, it's thought that two proteins in beer, malt and hops, may help nourish and strengthen your hair follicles. These beer proteins can bind with hair cuticles during washing, making them appear smoother and leaving your hair shinier after a wash. Some claim that the protein binds to hair dehydrated from blow drying, straightening and harsh weather, and restores strength and body to it. Anecdotally, people have also claimed that beer can reduce dandruff, cure an oily scalp, minimise hair loss and restore scalp health. Beer is also rich in vitamin B, which can apparently make your hair look shiny when applied directly.

But there are a few things worth noting. Firstly, none of this has ever been proven in any kind of trial to my knowledge, so there is no scientific evidence for it. It appears the only research that has been done is by the companies making the products. Online sources expound the nutritional benefits of beer such as its vitamin and mineral content, but it's hard to see how that would make much difference when applied directly to hair. Even when beer is drunk, these nutritional benefits are minimal. A true vitamin B deficiency will turn out hair that is dry and brittle, and if that was the case, you'd probably need a multivitamin to take by mouth instead of a topical treatment.

Furthermore, the alcohol it contains is likely to be dehydrating, so how can it outweigh the benefits of the proteins as described above? And frankly, do you really want to carry around the smell of beer with you all day?

So in short, I personally won't be tossing a can of Guinness over my hair anytime soon. Admittedly, I've never tried it, and I doubt it would do a lot of damage. But it seems like a wasteful use of a good brew... and perhaps drinking it would stop you worrying too much about your hair in the first place! ***NM***

CHARLOTTE LEE, VIA EMAIL

WHAT IS SOCIAL PRESCRIBING, AND IS THERE ANY BENEFIT TO IT?

Social prescribing is a way for primary care staff and other agencies to refer patients to a link worker. These are highly trained and have time to explore the person's health and wellbeing needs in a more holistic way. They can connect them to community groups and services for support. In particular, those with mental health problems, complex needs, multiple long-term conditions, or who are socially isolated, might benefit.

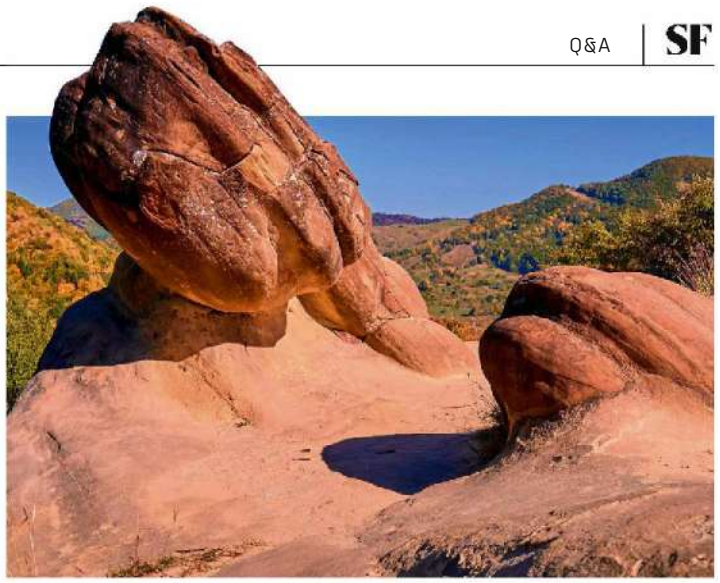
The link workers explore what really matters to the individual, and work in collaboration with local partners. Examples of social prescribing options include volunteering groups, financial advice services, group learning, arts activities and a range of sports. Green social prescribing entails linking people to more nature-based interventions such as local walking groups, gardening communities, and food-growing projects.

Studies have previously pointed to improvements in quality of life and emotional, mental and general wellbeing, alongside reduced levels of depression and anxiety from social prescribing. However, a review of eight studies in October 2022 suggested there was no consistent evidence that social prescribing improves social support, physical function, or reduces use of primary health services, and only limited evidence that it improves subjective assessment of personal health or quality of care received. However, the authors do acknowledge that social prescribing is designed to be different depending on the needs of the person and the resources in the local area, so determining if it works or doesn't work on a larger scale is difficult.

Overall, social prescribing is thought to be a more holistic way to address health issues beyond purely medical interventions, and patients have reportedly found it helpful for their mental and emotional wellbeing. ***NM***

ZARA WEBB, STAFFORD

WEIRD AND WONDERFUL: WHAT ARE TROVANTS?



Trovants are bulbous, otherworldly stones that grow over time, thus appearing to be alive. Parent rocks can even push out baby trovants, which then grow independently.

The sandstone structures are found mainly in Romania, with the most famous cluster in and around a village named Costeşti. There, a Trovants Museum Natural Reserve celebrates and protects them.

The stones' smooth curves give the appearance of modern, man-made sculptures. They feature heavily in local folklore, with people at one time believing them to be giant dinosaur eggs, plant fossils or alien creations. The word trovant was coined by a naturalist and means cemented sand.

The stones are formed from sand grains or rocks bound together by a limestone – calcium carbonate – cement. Geologists think that the trovants were shaped by earthquakes in the Middle Miocene, over five million years ago.

The stones vary greatly in size and shape, from centimetres to metres in diameter. Whereas most rocks erode and reduce in size over years, trovants continue to expand. During heavy rain, the porous trovants absorb substances, including calcium carbonate from the water. Limestone cement then oozes from the stones to add to their circumference. When water only hits one side of a rock, a blob can emerge, finally breaking free to create a new trovant.

Trovant growth is too slow to be watched in real time. It is estimated that the rocks have only grown a handful of centimetres in over 1,000 years.

The sandstone beds that the stones reside in hint at ancient aquatic environments, with successive sedimentation of material transported by rivers. Indeed, bivalve, and gastropod fossils can sometimes be found hidden inside the trovants. ***ED***

QUESTION OF THE MONTH

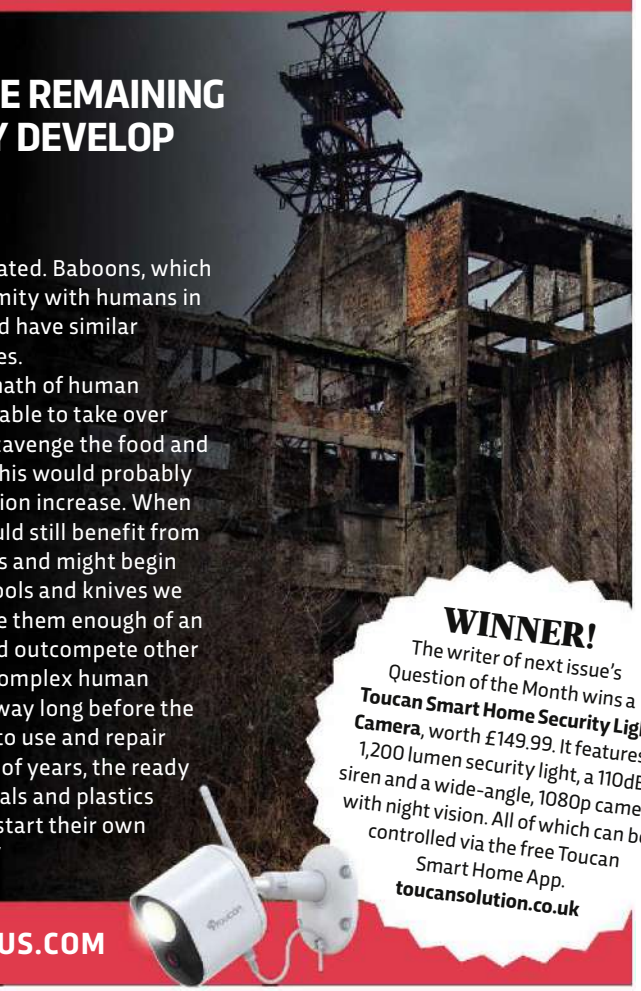
HARVEY SMITH, VIA EMAIL

IF A VIRUS WIPED OUT HUMANS WHICH OF THE REMAINING SPECIES WOULD TAKE OVER, AND COULD THEY DEVELOP TECHNOLOGY THAT WE WOULD RECOGNISE?

We tend to define dominance in terms of tool use, language and culture, and the ability to modify our environment. This is a very anthropocentric view that prizes the things we happen to be good at and ignores those we aren't. Bacteria outnumber and outmass us, have colonised more of the planet and will likely be here long after we have gone. For 99.9 per cent of the history of life on Earth, the planet has managed perfectly well without human-style intelligence and if we disappeared, there is no particular reason to suppose that anything would necessarily step up to take our place. Octopuses and dolphins are both already very intelligent, but living in the water rules out fire and electricity, so refining metals and building machines would be impossible for them. Evolving to live on land would be a 100-million-year endeavour.

Meanwhile, on land, existing primates would have a much easier time moving into the environments we had vacated. Baboons, which already live in close proximity with humans in South Africa, are social and have similar intelligence to chimpanzees.

In the immediate aftermath of human extinction, they would be able to take over human settlements and scavenge the food and livestock we left behind. This would probably result in a sudden population increase. When the food ran out, they would still benefit from the shelter of our buildings and might begin using some of the metal tools and knives we left behind. This might give them enough of an advantage that they would outcompete other primates and predators. Complex human machines would all rust away long before the baboons figured out how to use and repair them. But over thousands of years, the ready availability of refined metals and plastics might allow them to kick-start their own technological progress. ***LV***



WINNER!

The writer of next issue's Question of the Month wins a **Toucan Smart Home Security Light Camera**, worth £149.99. It features a 1,200 lumen security light, a 110dB siren and a wide-angle, 1080p camera with night vision. All of which can be controlled via the free Toucan Smart Home App.

toucansolution.co.uk

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X3 ILLUSTRATION: DANIEL BRIGHT

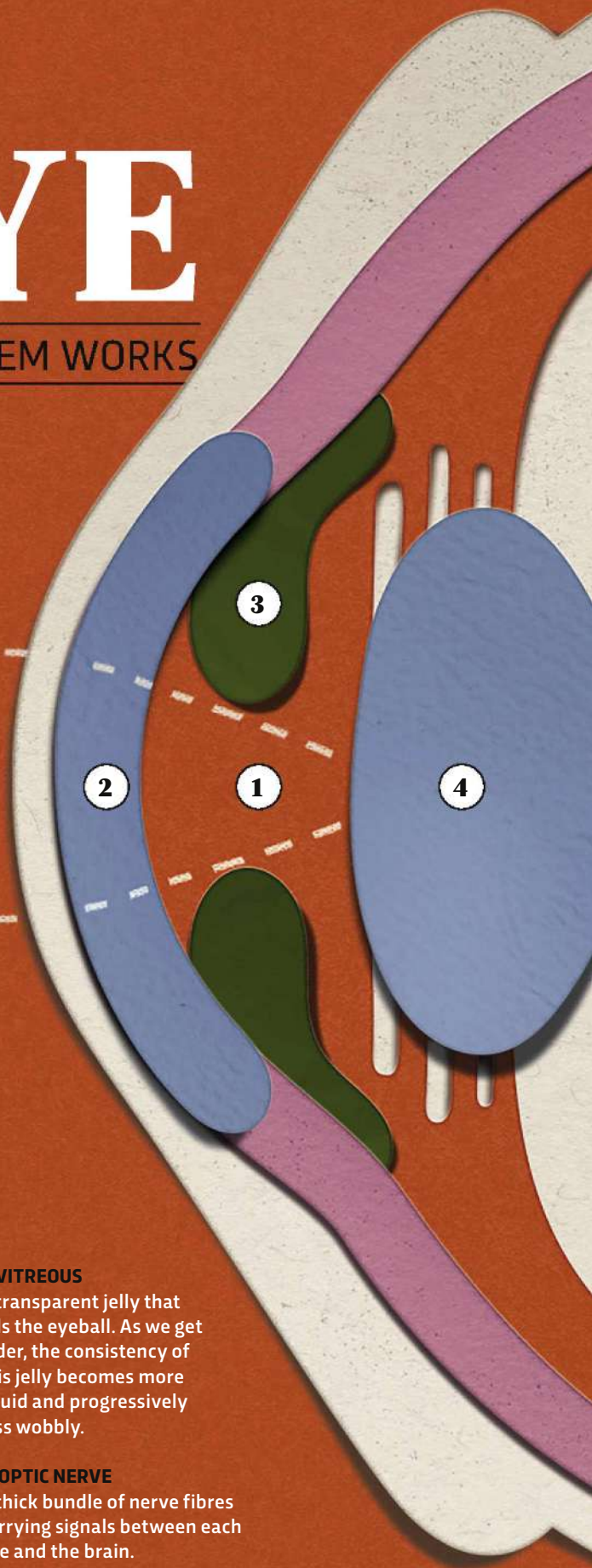
THE EXPLAINER

THE EYE

UNDERSTAND HOW OUR VISUAL SYSTEM WORKS

It's all in the eyes

Containing more than 100 million light-sensitive cells and some of the fastest muscles in our bodies, our eyes are capable of picking up everything from starlight beaming across the galaxy to the full gamut of human emotion. But it's in their coupling with our minds – through the approximately one million nerve fibres connecting each eye to our brains – that we gain the ability to synthesise slick visuals and interpret what's going on around us without getting distracted or overwhelmed.



What's inside my eye?

1. PUPIL
It looks like a black dot but it's actually a gap that lets light pass through to the back of your eye.

2. CORNEA
A transparent dome at the front of your eye, the cornea refracts light, helping to direct it along the right path to the retina.

3. IRIS
The coloured part of the eye that controls how much light gets in by causing the pupil to dilate or contract. The iris is part of a larger structure that forms a layer between the retina and sclera.

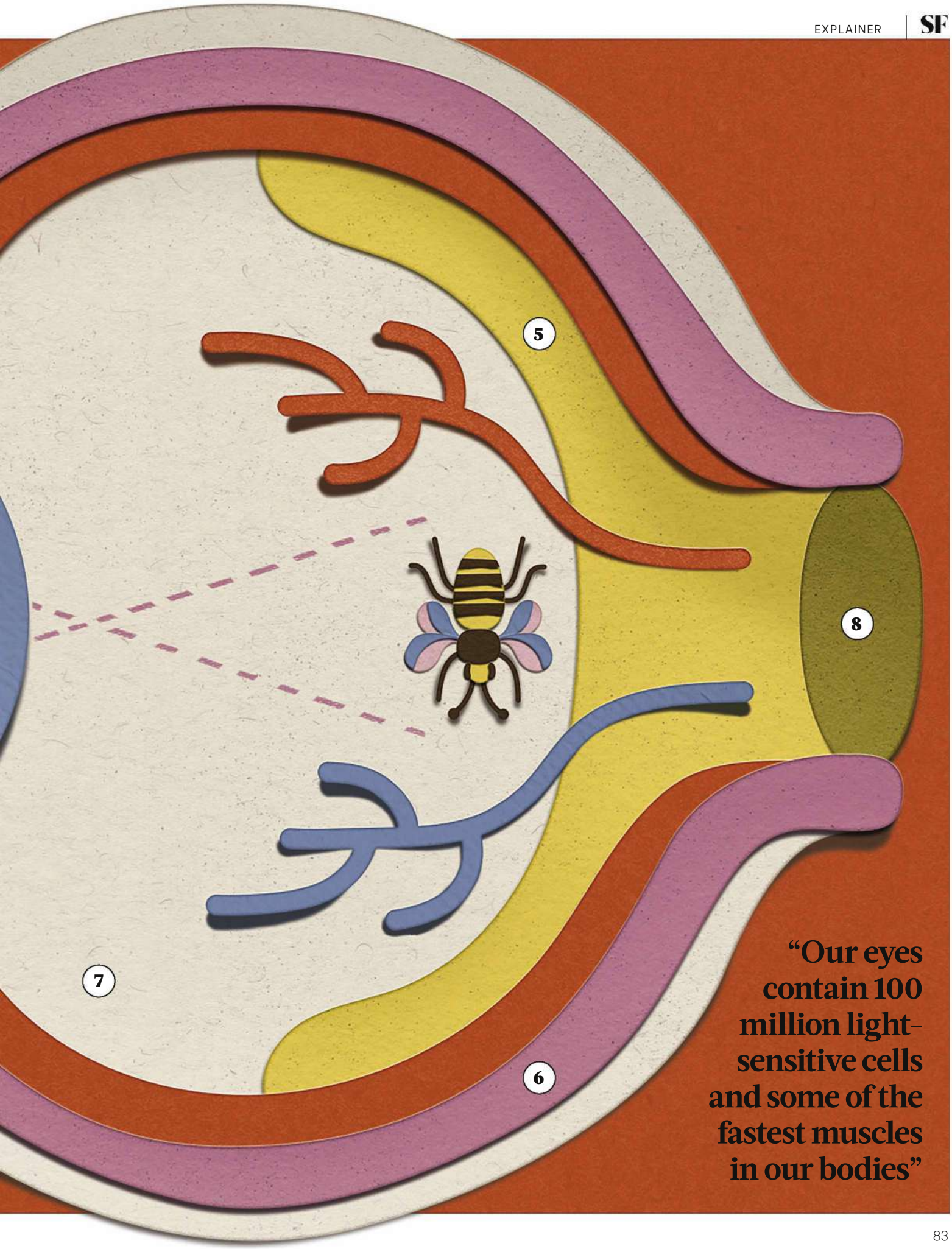
4. LENS
A transparent lens that changes shape to focus incoming light on the retina.

5. RETINA
Often thought of as the back of the eye, it's more correctly the innermost layer that the light hits after being inverted by the lens. The retina is jam-packed with light-sensitive cells and nerve cells.

6. SCLERA
Otherwise known as the white of the eye, the sclera is a protective, outer layer made tough by collagen fibres.

7. VITREOUS
A transparent jelly that fills the eyeball. As we get older, the consistency of this jelly becomes more liquid and progressively less wobbly.

8. OPTIC NERVE
A thick bundle of nerve fibres carrying signals between each eye and the brain.



"Our eyes contain 100 million light-sensitive cells and some of the fastest muscles in our bodies"

"Our brains are constantly processing what we see to provide a smooth visual experience, rather than giving us the effect of a shaky, handheld camera"

How do we see?

The simplest explanation is that what we see is a result of light entering the eyes through the cornea and lens, which direct and focus the light towards the photosensitive cells (rods and cones) in the retina. Rods work in low light, while cones require bright light but give us colour vision. Cones provide the details at the centre of our vision, while rods are responsible for peripheral vision. Together, these cells convert light into electric signals, which travel down the optic nerve to the brain.

What we actually see, though, is as much about how our brains interpret these signals so that we can make sense of the information we're receiving without being distracted by unimportant details. This visual prioritisation and filtering produce a 'mental image' that is only a representation of what is actually there.

For example, our brains prioritise faces, with the result that we're always spotting them where they don't exist – such as in clouds and wallpaper patterns. Our brains are also constantly processing what we see to provide a smooth visual experience, rather than giving us the effect of a shaky, handheld camera. Recent research suggests it does this by blending together the inputs from the previous 10-15 seconds, meaning what we see isn't necessarily a second-by-second update but it does give us a less hectic sense of the world.

How do our eyes compare to cameras?

It's hard to compare because what we see isn't made up of pixels or frames, and we're constantly switching where we focus.

It's been suggested that our eyes have the resolution (ability to distinguish two points) of a 576-megapixel camera. A stills camera capable of capturing 576 million separate pixels within a single image would be five times better than some of the highest resolution cameras currently on the market. However, our eyes only see with very high resolution at the centre of our vision. So, everywhere else, the resolution is much more comparable to a standard camera.

As for colours, we can only see those that fall into the small range of wavelengths visible to humans (400-700 nanometers), whereas we've built cameras that are capable of perceiving the shorter wavelengths of ultraviolet light (10-400nm) and the longer wavelengths of infrared (750-15,000nm).

Within the visible spectrum, most people are thought to be able to discriminate around 10 million different shades using three types of cone cells. This system is not dissimilar to that of a camera, which combines red, blue and green pixels to capture nearly 17 million colours. But people with tetrachromacy have a genetic mutation that gives them an extra cone type, allowing them to see 100 times more colours – like birds and reptiles.

How does ageing affect our eyes?

Our vision deteriorates as we get older. In middle age, the lenses in our eyes become less flexible, making it harder to focus close-up, which is why many people start needing glasses for reading in their 40s and 50s. A number of age-related conditions are also leading causes of blindness.

20/20 vision

Everything looks good, whether it's close-up or away in the distance.

Glaucoma

Loss of peripheral vision, thought to be associated with increasing pressure, due to fluid build-up, damaging the optic nerve.

Macular degeneration

Loss of central vision, caused by death of the light-sensitive cone cells in the macula – the central part of the retina.

Cataracts

General clouding of vision caused by protein breakdown and clumping in the lens. Most people will eventually develop cataracts.

ILLUSTRATIONS: HARRIET NOBLE

FIVE COMMON MYTHS ABOUT THE EYE... BUSTED

1.

WE'RE BORN WITH ADULT-SIZE EYES

Nope. A baby's eyes are large in comparison to its face but they're only between one and two thirds of adult size. Eyes grow rapidly for the first year, then again during puberty and don't stop until you're around 20.

2.

20/20 VISION IS PERFECT VISION

Not really. It means you can read all the letters on an eye chart from a distance of 20 feet (6 metres). 20/10 vision is better: you can see details that other people can only see when they stand 10 feet (3 metres) away.

3.

DOGS CAN ONLY SEE IN BLACK AND WHITE

Wrong again. Dogs can see in colour but they see mostly yellows and blues. They have fewer types of the cone cells needed for colour vision compared to humans.

4.

YOU CAN'T SNEEZE WITH YOUR EYES OPEN

You can and it's okay... your eyes won't pop out of your head. This is probably another one of those things that overanxious parents came up with.

5.

CARROTS HELP YOU SEE IN THE DARK

This one's sort of true. Carrots contain beta-carotene, which we use to make vitamin A. This, in turn, is converted into pigments that we use to see in low light.

ILLUSTRATIONS: HARRIET NOBLE

Why do people have different eye colours?

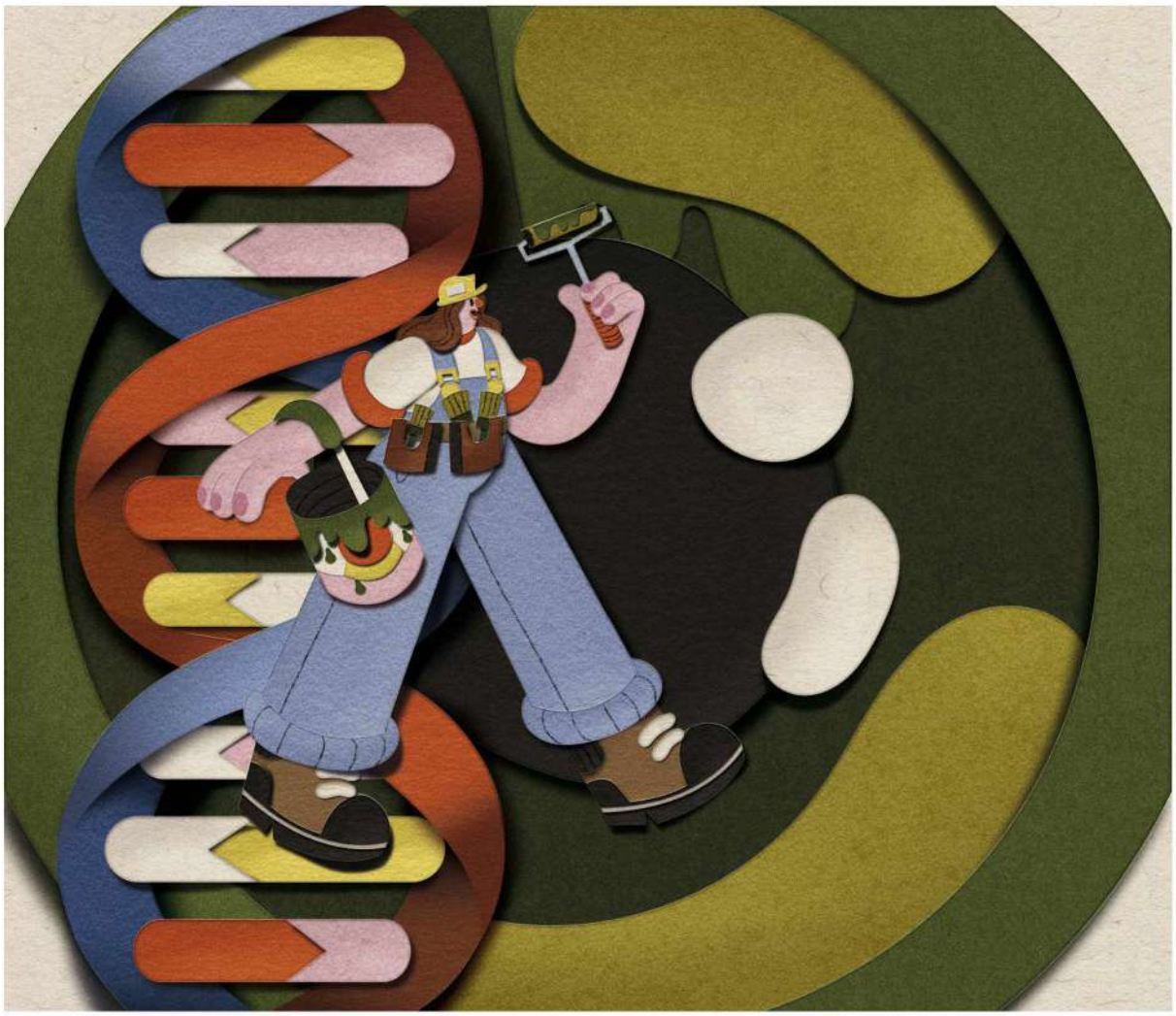
Recent research suggests there are at least 61 genes for eye colour – and that's just in European and Asian people. This means that, contrary to what we might have been taught at school, it's not that straightforward to work out what colour eyes a child born to two blue-eyed parents should have. (It's quite possible, although less likely, for them to have brown eyes.)

But what is it in the iris that makes it blue or brown?

Well, dark irises contain more of the naturally brown, light-absorbing pigment melanin – the same pigment that gives our skin different colours. Blue irises that contain less melanin absorb less light and instead reflect and scatter it, producing short wavelengths of light at the blue end of the spectrum. Differences in melanin levels also explain why some people have two different-coloured irises (heterochromia), usually the result of a harmless genetic mutation affecting melanin development in the eye.

Meanwhile, in babies whose eyes are blue but later turn brown, their melanin is still forming. In fact, babies were once the only humans with blue eyes, because the genetic mutation responsible for adults having blue eyes is not thought to have appeared in European populations until the last 6,000-10,000 years.

"In fact, babies were once the only humans with blue eyes"



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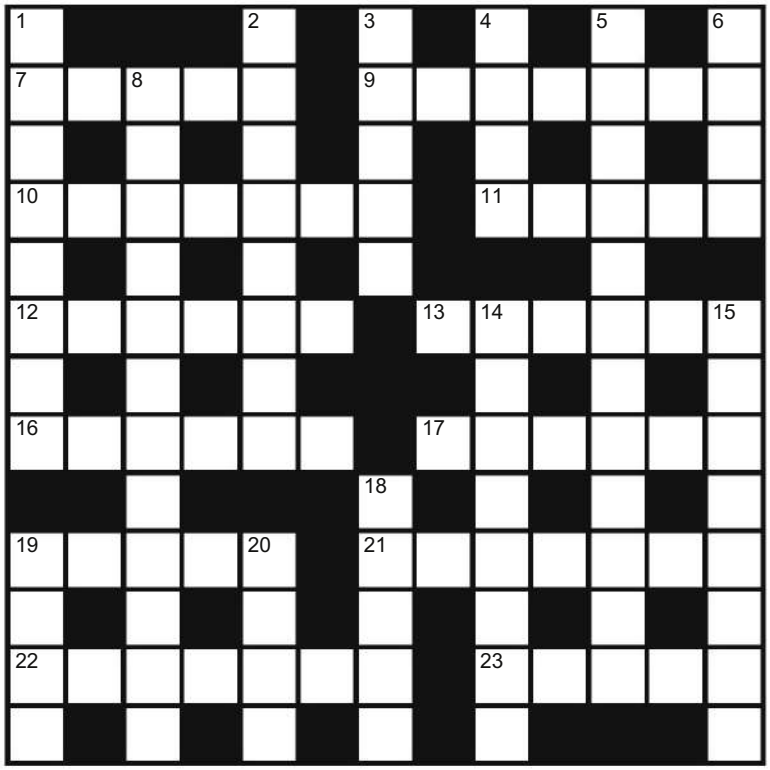
CROSSWORD

PENCILS AT THE READY!



ACROSS

7 Struggle to take leaders out some fruit (5)
9 Old Scot catches socialist forecast (7)
10 Curl developed on that woman's dog (7)
11 Game girl, good at heart (5)
12 In igloo, Myles is downhearted (6)
13 Cunning, bad-tempered woman and daughter (6)
16 Lets us organise fight (6)
17 Artist on jetty - that's sharp (6)
19 Beg to remove strange tree (5)
21 Almost tolerating a replacement (5-2)
22 Prefer a slope (7)
23 Owns German domain within terrible place (5)

DOWN

1 Note with an insult to Victorian setting (8)
2 Yours truly put bleach, foolishly, around sauce (8)
3 Small wine, just for fun (5)
4 Dam is almost strange (4)
5 Determined to be unmarried and looked after (6-6)
6 Go off course without right support (4)
8 Preposition for one section of lecture (4,2,6)
14 Senior teacher handled each nuisance (8)
15 Drake swimming around new ship in the gloom (8)
18 Something valuable, when arranged (5)
19 Important to get ringleader in prison (4)
20 Greet a shower of stones (4)

ANSWERS

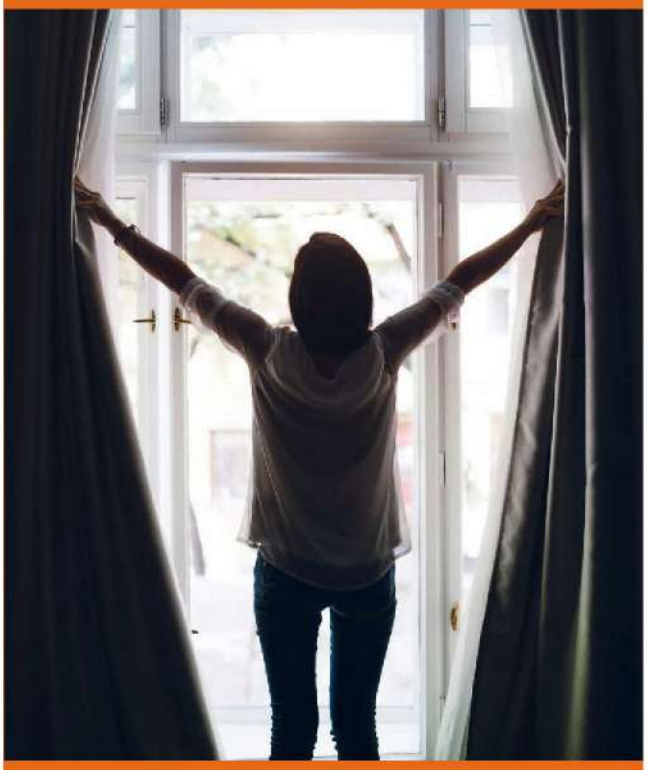
For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

RISE AND... SHINE?

How to wake up feeling rested, according to science



PLUS

BEES EXPLAINED

How smart are they? How do they communicate? And what should I plant to create a bee-friendly garden?

KILLER FUNGUS

Meet the fungal spores turning insects into zombies and consuming them from the inside out

ON SALE 6 JULY

SF

POPCORN SCIENCE

Could humans ever run at supersonic speeds?

Is there a biological limit to how fast humans can run? Or will we all be sprinting like The Flash in future?

by **STEPHEN KELLY**

There is no firm consensus on how fast The Flash, the DC universe's speediest superhero, can run. One story clocks him at 2,535 miles per hour (over 4,000km/h), for instance, which is faster than most fighter jets. While in Zack Snyder's *Justice League*, he runs faster than the speed of light, 186,000 miles per *second* – so fast, in fact, that he violates the laws of physics and turns back time. What is certain, however, is that for the likes of you and me, running at those speeds would be as unlikely as they would be perilous. Our faces would melt, our legs would break apart… I can barely do the 'Couch to 5K' plan as it is.

So how fast *can* human beings run? For that, we would need to look at the closest thing humanity has to The Flash: retired sprinter Usain Bolt. In 2009, Bolt set a new world record by running the 100m sprint in 9.58 seconds – achieving a top speed of 27mph (43km/h) – at the World Athletics Championships in Berlin. It's a record that is yet to be broken and, according to Mark Denny, a biology professor at Stanford, perhaps never will be.

In 2008, a year before Bolt broke the world record, Denny published a paper analysing the top speeds of various athletics competitions – as well as those of greyhound and horse races – since the 1920s. And in many cases, he found the same pattern. "Performances were clearly plateauing in all races," he says, "and has plateaued in some of them." He found that horses, for example, reached their limit with Secretariat in 1973. "No horse has come close to the records he set," says Denny. "They keep breeding horses to go faster and they just keep breaking down. The limits are real."

As for humans, Denny has used his data to make a bold prediction: no human being will ever run the 100m sprint faster than 9.48 seconds, just 0.1 seconds under Bolt's current record. "There was a real sense of disappointment in response to the paper [with the prediction]," he says. "People didn't like the idea of an Olympics where world records wouldn't be broken. There was a chance that Bolt could have done it in 9.48 but then he aged out on that. I was rooting for him to break it."

According to Denny, the reason for this proposed plateau is due to the basic biological limits of the human body. Four-legged animals like cheetahs – with their long legs, light body weight and flexible spine – are designed for short-term speed. Bipedal runners, meanwhile, are built for endurance.

"Muscles can only contract as fast as the actin and myosin [two key components of muscle fibre] can turn over," he says. "You can get some advantage by making longer filaments in the muscle but then you can only make them so long.

Usain Bolt is 196cm tall. You might get somebody who is 218cm and really well proportioned. Yet even then, tendons and bones can only put up with so much. Even if you made the bones more robust, they would then be heavier, negating what you're trying to do."

The only way you could go beyond these biological limits, says Denny, is with genetic engineering. Although don't go expecting us to be trotting around like centaurs any time soon. "It's more likely to be used to gain more powerful muscles and longer legs," says Denny.

"Or to tweak the design here and there: 'let's move this particular muscle to a different place' and so on. That's going to be really strange. Performance-enhancing drugs are scary enough but I hope I'm not around to see that." **SF**

VERDICT

Unless future humans play fast and loose with their bone and muscle structures, our built-in top speed is unlikely to be bettered.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATION: DALE EDWIN MURRAY

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Will you make that promise to generations to come? Please, leave a gift in your Will to the Stroke Association.

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Rebuilding lives after stroke

The Stroke Association is registered as a charity in England and Wales (No 211015) and in Scotland (SC037789).
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Stroke Association

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